INDIAN NATIONAL SCIENCE ACADEMY
GOLDEN JUBILEE CELEBRATIONS — 1984

PROCEEDINGS

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FOREWORD

In January 1935 the Indian National Science Academy (then National Institute of Sciences of India) was formally established and the inaugural meeting of the foundation of the Academy was held in Calcutta under the Chairmanship of Dr J H Hutton, President of the Indian Science Congress Association for that year. The year 1984 is thus the Academy's Golden Jubilee year. The celebrations were inaugurated on 16 January at Vigyan Bhavan by the Prime Minister of India, Smt. Indira Gandhi in the presence of a large and distinguished gathering comprising eminent scientists and men of letters from this sub-continent and abroad.

A series of special lectures and presentations, including the Fifth Blackett Memorial Lecture by Sir Andrew Huxley, President of the Royal Society, London by distinguished visiting and national scientists were organised as part of this inaugural jubilee celebrations.

This souvenir volume presents the proceedings of this historic and memorable event. I am confident that this volume would be of permanent interest and lasting value to the scientific community, commemorating as it does, the 50th anniversary of the premier scientific academy in this country, representing all branches of science and committed to the promotion of excellence.

To me personally, it has been a matter of great privilege to occupy the office of the President of the Academy as it approached this great landmark in its history and to have had the pleasure of organising the various programmes of the Golden Jubilee, with the active support and cooperation of the Council, the Past Presidents and the entire Fellowship. To all of them I express my deep gratitude.

A.K. SHARMA
President
Indian National Science Academy
New Delhi

September 1984.

INAUGURAL FUNCTION

Sixteenth of January 1984 marked the beginning of a truly historic event that brought felicitations and greetings from the world of science everywhere as the Indian National Science Academy entered its 50th year. The Prime Minister of India, Shrimathi Indira Gandhi inaugurated the Golden Jubilee Celebrations in the presence of a large and distinguished gathering comprising eminent men and women of science from within the country and outside including Afghanistan, China, France, Hungary, Japan, Malaysia, Nepal, Norway, Pakistan, Poland, Singapore, Sri Lanka, United Kingdom, United States of America, and Union of Soviet Socialists Republic. The venue, Vigyan Bhavan (Science House) lent its own image and aura to the August occasion. It was here that the first Session of the General Assembly of UNESCO held in the Continent of Asia was convened 27 years ago.

WELCOME ADDRESS

The proceedings began with a Welcome Address by the President of the Academy, Professor A.K. Sharma. The Address traced the genesis of the Academy and the highlights of its 50 eventful years from its beginnings as the National Institute of Sciences of India in Calcutta in 1935. He presented an overview of programmes and activities of the Academy in the context of its Charter of Objectives for the generation of knowledge, promotion of excellence, execution of programmes of national and international relevance, dissemination of knowledge and popularization of science

through Academy's publications, and safeguarding the interests of scientists. Professor Sharma also outlined the new activities and programmes initiated in the Golden Jubilee Year in various spheres. These include the construction of a science complex on the premises of the Academy to provide space for the expanding programmes for which he appealed for the larger financial assistance and donations.

The President referred to the Academy's activity of identifying young talent through selection of young scientists which had come to be regarded as the highest form of recognition a young scientist could aspire to in this country. The success of the programmes is reflected in the fact that 80 per cent of the young scientists have been able to secure a congenial atmosphere in persuit of research within the country, thus underlining the need for further strengthening of the programme in the Jubilee Year. It had also been decided to suitably utilize the services of INSA Fellows who were active in research after their retirement in the preparation of scientific documents, programmes and projects, both of applied and basic character.

Concluding, the President stressed the need for maintaining the autonomy of the Academy to help promote excellence, generate a wide base of scientific knowledge and advise the Government on issues of national relevance. The expanding activities require additional financial resources which the Academy was striving hard to obtain. He expressed the hope that these needs would be met by the Department of Science and Technology and the Academy would be accorded the status which it deserves as the supreme scientific organization in the country.

The full text of the President's Address appears on page 33

INAUGURAL ADDRESS

The Prime Minister, well known for her liberal and enthusiastic support to the pursuit of science, described the occasion as 'Something special' – the Golden Jubilee of an organization recognized as the premier society representing all branches of science in India. She referred to the founding of the Academy by pioneering scientists long before India became free and the coming into being of other academies in arts and the sciences soon after 1947 under the inspiration of Jawaharlal Nehru and Maulana Abul Kalam Azad who symbolised resurgence of India's march towards progress.

Shrimathi Gandhi talked of similar developments that had taken

place in other countries with the emergence of modern science, notably in Great Britain, France, Italy, USSR, etc., and the role played by the professional societies in the advancement of knowledge. She referred to a provocative statement: 'Art is I, Science is we' suggesting that art is an individual pursuit and science, a corporate one. This statement was widely noted and repeatedly referred to by eminent speakers during the celebrations.

The Prime Minister spoke of the role of the Academy in providing opportunities to scientists in different disciplines to consider the larger problems of science through cross fertilization of ideas and in guiding major national decisions in matters of development, defence and education. She wanted the Academy to examine to what extent science and technology in India had been decisive agents of dynamic and beneficial change. The Government had fully involved scientists in policy making and the people were eager to benefit from modern knowledge whether it be to raise greater yields from their fields or to find better cure for their ailments, she said.

Concluding her inspiring and thought-provoking address, Shrimathi Gandhi pleaded for international co-operation in science to reduce disparity between the technologically developed and developing countries while steering clear of the forces of domination and exploitation. The only way to achieve this, she noted emphatically, was through development of indigenous capabilities in science and technology in all communities and in all parts of the world.

The Prime Minister offered her warm felicitations to the Academy and expressed the hope that it will set the highest standards of professional conduct and intellectual and moral responsibility.

The full text of the Prime Minister's Address appears on page 39

PLAQUES AND PUBLICATIONS

One of the highlights of the function was the presentation of Golden Jubilee Plaques by the Prime Minister to Foundation Fellows and Past Presidents of INSA and representatives of collaborating academies. It was indeed a treat to witness the venerable men of eminence and celebrities in the world of science, some of them in their 80's and 90's walk up the dais to receive the honours as the Prime Minister exchanged pleasantries with them and expressed her pleasure and appreciation. The list of recipients of the plaques is given on page 28

The Academy President on behalf of the Fellowship of the Academy then presented to the Prime Minister a souvenir in appreciation of her sustained interest and continued support to the cause of science in India.

The Prime Minister unveiled a model of the new Science Complex of the Academy for which an initial donation of Rs.10 lakhs was announced by Dr Biren Roy of Calcutta, an aeronautical engineer of repute. The Science Complex will provide the much needed space for the expanding national and international activities of the Academy and will have guest room facilities to accommodate visiting scientists from within the country and overseas.

Earlier, the Prime Minister released a number of prestigious Golden Jubilee Publications brought out by the Academy on the occasion. These include the following:

1. Compendium of Fellows of the Indian National Science Academy, past and present-biographical notes.

2. Science in India - A Changing Profile Edited by S.K. Mukherjee and B.V. Subbarayappa - presenting a perspective on the major aspects of the scientific tradition in India, the advent and growth of western science before independence and the manifold developments in science and technology since independence.

3. Antarctica - the unknown continent of unexplored wealth by S.Z. Qasim and L.U. Joshi.

4. Medal Lectures - a collection of lectures in two volumes delivered by eminent men of science who have been recipients of various medals and honours from the Academy.

5. Addresses by Presidents - 1935-1984.

6. A number of Perspectives and Status Reports on different subjects by eminent authors. The titles so far published are listed on page 30

VOTE OF THANKS

With his characteristic suavity, Professor M.G.K. Menon, Member, Planning Commission, and immediate Past President of the Academy, gave the finishing touches to this solemn and dignified function. He said the Academy was indeed privileged to have the Prime Minister inaugurate the Golden Jubilee Celebrations. The

occasion had brought together very distinguished scientists from distant lands to participate in the event. It was only through cooperation among the scientists of the world that there could be hope for a better future for mankind. The Prime Minister had befittingly reminded the scientists of the need to look at the past achievements in terms of the science policy resolution adopted by the country, both in terms of development of our society and international cooperation and amity.

GREETINGS AND FELICITATIONS

The Academy received a number of mementoes, messages and greetings felicitating INSA on its Golden Jubilee Anniversary from collaborating academies and societies in various parts of the world. We reproduce here some of these messages.

Chinese Academy of Sciences, Beijing

We wish to extend our warmest congratulations to you and your colleagues on behalf of the Chinese Academy of Sciences on the occasion of the Golden Jubilee Celebrations of your Academy. We are very pleased to note that your scientists have made great efforts in the development of science and technology in India and have scored gratifying results. For this reason, we wish to convey to you our best greetings.

Both China and India are developing countries. Scientists of our two countries are confronted with the need of developing science and technology. It is therefore in our common interest to promote academic exchanges between our two countries, learn from and complement each other in our endeavours to build up science and technology in our two countries.

We sincerely wish the Golden Jubilee Celebrations of your Academy every success and even greater success for your Academy in 1984.

LU JIAXI, President

YAN DONGSHENG, Vice-President

L'Academie des Sciences de L' Institut de France, Paris

Les membres de l' Academie des Sciences de l' Institut de France adressent à leurs confreres de l'Académie Nationale des Sciences de l'Inde leurs souhaits les plus chaleureux et leurs bein vives felicitations à l'occasion de ce Jubile d' Or.

Ils se felicitent des liens étroits et des relations regulieres déjà entretenues entre les deux Academies, auxquels la signature recente d'un protocole apporte encore un nouveau et important témoignage de coopération.

Ils forment des voeux pour qu'en union avec la communauté scientifique internationale, l'Académie Nationale des Sciences de l'Inde poursuive sa feconde carriere pour le plus grand bénéfice de la Science et de la Paix.

Les Secretaires Perpétuels
PAUL GERMAIN
ROBERT COURRIER

Le President
JEAN BERNARD

Le Vice-Président
ANDRE BLANC—LAPIERRE

The Academy of Sciences of the Institute of France, Paris.

The members of the Academy of Sciences of the Institute of France extend to their fellow members of the Indian National Science Academy their warmest wishes and heartiest congratulations on the occasion of their Golden Jubilee.

They are happy that close and cordial relations exist between the two Academies. The recent signing of the protocol marks a new and important step towards cooperation between the two Academies.

Such collaboration among the international scientific community, the members hope, would augur well for pursuit of fruitful programmes and activities by Indian National Science Academy for the greatest benefit of science and world peace.

PAUL GERMAIN
ROBERT COURRIER
Permanent Secretaries

JEAN BERNARD
President

ANDRE BLANC—LAPIERRE
Vice-President

Polish Academy of Sciences, Warsaw

On the occasion of the Golden Jubilee of the Indian National Science Academy, the Polish Academy has the honour to offer its sincere greetings and congratulations.

Indian scientists in various fields have, through their constructive researches, created for themselves an impressive image in the world of science. On the occasion of its Golden Jubilee celebrations, the Polish Academy of Sciences wishes to express its feelings of admiration and friendship for the Indian National Science Academy. We are convinced that with greater collaboration between scientists of our two countries, there would be opportunities to work for the all round development of science in the service of humanity and for consolidation of world peace.

LEONARD SOSNOWSKI
Chairman

The Royal Society, London

The Royal Society of London for Improving Natural Knowledge sends warmest greetings and congratulations to the Indian National Science Academy on the occasion of its Golden Jubilee.

Many of the strong and varied links between the scientists in India and those in the United Kingdom are long standing and of great mutual benefit. The exchange agreement between the Academy and the Royal Society has recently been revised to accommodate a substantially greater number of visits and we are confident that these will be most fruitful.

The Society wishes the Academy every success as it now moves forward to its centenary.

ANDREW HUXLEY
President

US National Academy of Sciences, Washington, D.C.

On behalf of our National Academy of Sciences, I send you and all of our Indian colleagues sincere congratulations on the occasion of the Golden Jubilee Anniversary of the Indian National Science Academy.

I am particularly sorry not to be able to participate in this auspicious occasion because we have had a long-standing and highly rewarding association with INSA and its distinguished members.

We are delighted that through the new Indo-US scientific initiative recently inaugurated, we will continue our close association with the Indian scientific community in cooperative research. As you know, we have been asked by our Government to establish a high-level scientific panel to work with Indian colleagues to review the research program and plan future activities. We feel confident that this new development will serve to further strengthen scientific ties between our countries.

Your American colleagues join with me in wishing INSA all success in its tradition of furthering the progress of Indian Science, which has already contributed so much to science worldwide.

FRANK PRESS
President

USSR Academy of Sciences, Moscow

The USSR Academy of Sciences extends its cordial greetings and congratulations to the Indian National Science Academy on the occasion of its 50th anniversary celebrations.

The Soviet scientists are well aware of the role of the Indian National Science Academy in the fields of education, dissemination of scientific knowledge and in tackling numerous complex problems resulting from the colonial past of the country. The Academy has played a notable role in the utilization of scientific achievements for accelerated development of industrial and agricultural production with the aim of raising the living standards of the Indian people. The Indian scientists have greatly contributed to the progress of the world's civilization and the names of many Indian scientists and thinkers of the past constitute the pride of both India and world peace.

The present generation of Indian scientists is making valuable contributions to the development of science and culture in India and enriching the treasure of world science. A versatile cooperation has existed between the scientists of our two countries to solve scientific problems and strengthen the bonds of friendship between the peoples of USSR and India. This cooperation, we are sure, will continue to grow for the benefit and progress of scientists in both the countries and in the larger interest of world peace.

On the occasion of the Golden Jubilee, the USSR Academy of Sciences sincerely wishes the Indian National Science Academy every success in its activities and good health and personal happiness to the members of the Academy.

ACADEMICIAN ALEXANDROV
President

LECTURES AND PRESENTATIONS

HIGHLIGHTS

Following the Inaugural Function, the venue of the celebrations for the next two days (18-19 January) shifted from Vigyan Bhavan to the Academy Auditorium in New Delhi. The Golden Jubilee Steering Committee of INSA had lined up a sumptuous fare for the Fellowship, guests and the distinguished audience who had the unique experience of hearing from the same platform in quick succession a galaxy of scientists and visiting academicians. A summarised version of these lectures is presented here while the full texts are reproduced later in the volume.

FIFTH BLACKETT MEMORIAL LECTURE

SCIENCE AND POLITICS

SIR ANDREW HUXLEY N.L.

Recalling his close association with Lord PMS Blackett, the noted British scientist, Sir Andrew Huxley, President of the Royal Society, London, said that 'Science and Politics' was a very suitable topic for the lecture because Blackett divided his immense energies between these two aspects of human activity.

Though science and politics are very different kinds of human activities, there are analogies between them. While politics could be called the art of the possible, science was the art of the soluble. These phrases are not definitions of politics or science. These are statements of some of the methods which one has to use in these activities and if one attempts the definition of politics or science, one has to define them in terms of one's aim or the abilities of what one is trying to do with these activities. Sir Andrew continued "I might say that politics perhaps is the art of managing people by persuasion and in my cynical moments I used the phrase, politics may be defined as the craft of persuading others to act in one's own interest, while science is the systematic efforts to understand and to control nature and in the definition, I think, one has to impute the statement that it implies experiment and observation to check one's ideas which is an essential feature in science.

GOVERNMENT SUPPORT OF SCIENCE

Speaking of interaction between science and politics, Sir Andrew first made a distinction between basic science on the one hand and applied science on the other. Pure science or basic science is the research which has the recognisable prospect of indirectly leading to practical application as compared to applied

science where one is aiming for a particular development but one may be able to see that the particular line of investigation is likely to have application in future. Work done with this aim in view of longer term practical use is what is called strategic. Another definition of strategic research programme is to say that it is a work which is pure from the point of view of the investigator but applied from the point of view of his employer.

Sir Andrew thought that both the scientists and politicians have ambivalent feelings about each other's activities. Scientist wants and indeed needs money from Government but he does not want to be controlled by Government. If he is controlled, he may claim absolute right or complete academic freedom to be able to pursue his own personal scientific interests without any further consideration. But no Government can be interested to give unlimited funds for a purpose of that kind. Politician, on the other side, is glad with the international prestige which comes from scientific discoveries made in his country, but may suspect the scientist of having too international a view.

The politician rightly recognizes the value of applied science in contributing to industrial and economic success of his country. He probably recognizes to some extent the importance of strategic science because it will lead to applied work of a longer time scale. In any country like Britain and India, which depend on the popular elections at very frequent intervals, many if not all politicians think of a time scale which is limited by the approach of the next election and this is too short a time scale for considering pure research as a source of future national wealth. It becomes difficult for a politician to justify large scale expansion on pure scientific research.

So there is this difficult question of how much of pure science or strategic research is a country able to afford. If the country relies on other countries for its basic science, it is easy to say that one can read about this in the journals and apply it in practice, but with the speed with which new developments come into application, it is widely recognised that there is a serious flaw in this argument. It is only, if one has scientists who are actually engaged in the current advances, that one is likely to be able to recognise the potential applications or never be able to get near the lead in making practical application.

The learned speaker expressed his sympathy and agreement with the Prime Minister's Address the previous day when she spoke of the need for scientists to concern themselves deeply with the problems of the villages in India. But he added that while it was right that some scientists must concern themselves with applied

science, it was unreasonable to expect every scientist to switch his energies into the short term and urgent needs of his country. This may be a shortsighted policy because squeezing the poor scientist in this way may not divert him into industry. It may cause him to emigrate, and this perhaps was an appreciable problem in Britain, and it was one of the great problems facing India.

ADVISING THE GOVERNMENT

Sir Andrew proceeded to deal with another aspect of the interaction between science and government, namely, tendering scientific advice to government on general problems of policy. This, he said, was one of the important functions of the Royal Society and possibly of the Indian National Science Academy. This matter of giving advice on general policy is relatively easy and certainly straightforward as long as problems are of purely technical or scientific in nature. But very few of the problems on which Government want advice are of this simple character. Almost invariably there is a political component in the sense that the solution to the problem has implications relating to the advantage of one section of the population as against another.

Sir Andrew felt that scientists have indeed a claim to be listened to on matters where they have special confidence. But there was a great temptation to go beyond one's range of speciality to give advice for, either consciously or unconsciously, pressing one's point of view on another in areas where the scientist has no special claim to be listened to beyond the claim of any citizen. This is one of the difficult aspects of relation between science and politics. If scientist carefully avoids going appreciably outside his range of special knowledge, he will retain credibility with the people he advises, and that he will be in a position to claim to be listened to with particular attention in the fields where he has got special knowledge.

TREATMENT OF SCIENTISTS

On the treatment of scientists who disagree with the regimes of the country in which they live, Sir Andrew said, the scientist had to judge between the genuinely humanitarian need for a protest against improper treatment, particularly of scientists in those countries, but he must at the same time keep himself separate from the propaganda which one country may be using against another and in which this question of inhuman treatment of individual scientist is being used as a propaganda weapon. These are many of the tight ropes that scientists and scientific academies have to walk all the time.

AUTONOMY

Another tight rope is trying to maintain the independence of scientific academies. We will seek funds from the Government in varying degrees when we wanted but at the same time we must keep our independence, so we can give a genuine scientist's view on whatever matter we may feel it proper to speak on and also to our government or any one else by receiving an overwhelming share of funds from one source. He who plays the piper, does in some degree, call the tune.

The full text of the lecture appears on page 43

FIFTY YEARS OF PARTICLE PHYSICS

M G K MENON

Member, Planning Commission, New Delhi.

Prof. M G K Menon, eminent physicist and Immediate Past President of the Academy, traced developments in the growth of particle physics over the past half century and the evolution of whole new concepts to explain the basic forces in nature i.e. strong electromagnetic and weak interactions.

He referred at length to the proton decay experiments which have been in progress for the last 25 years in Kolar goldfields at depths of over 3,000 metres which is not available anywhere except in the gold mines in South Africa. The work might provide an insight into the relationship between microstructure of the atom and the macrostructure at the cosmological level. Similar experiments were in progress in the U.S., France and Japan and the Indian experiment might constitute an important contribution in framing the grand unification theory. The experiment had so far detected five candidate events' which could correspond to proton decay.

Prof. Menon pleaded that more experiments of this type should be conducted in different parts of the world through collaborative endeavour in the true international character of science.

Note We regret that due to non-availability of the script of the lecture at the time of going to press, we could not publish the full text

SOME APPLICATIONS OF SIGNAL PROCESSING IN SPACE AND MEDICAL TECHNIQUES

A.BLANC-LAPIERRE

Vice-President, French Academy of Sciences, Paris.

Professor Lapierre in his learned discourse outlined some recent applications of signal processing techniques to domains as wide apart as spatial communications and medical imaging.

He began with reviewing some basic concepts or properties in signal processing and then dealt with transmission of information over long distances, including application to deep sea space problems. In regard to studies in the medical field, the problem was to obtain data concerning the morphological conditions and the functions of some human organs and to detect possible impairments. Concluding, Prof. Blanc-Lapierre observed that the field of application of ideas, of reasoning modes, and of the techniques of information theory and signal processing was very vast, especially when they are supported by possibilities of computer science. There is no doubt that these ideas generate links and unity factors between various scientific domains, and constitute an invaluable tool for the advancement of what can be called System Theory, which has by no means reached its zenith yet.

The full text of the paper appears on page 57

IMPULSE ACTIVITY NOT THE SOLE DETERMINANT OF SKELETAL MUSCLE FIBER TYPE

T P FENG

Vice-President, Chinese Academy of Sciences and Director, Shanghai Institute of Physiology, Shanghai

Professor Feng reviewed recent developments in his own field of research, namely, studies on muscle fiber types. Recent work during the last twenty years or so had shown that muscle fiber undergoes plastic transformation from one type to another with cross-reinnervation, that is, with exchange of the nerve supplies between the fast and slow muscles. How does the motor nerve determine the muscle fiber type? Is impulse activity the sole neural determinant of muscle fiber type? Prof. Feng described the experiments carried out by him and his collaborators which shed light on these questions.

The full text of the paper appears on page 72

UNIVERSITY–INDUSTRY RESEARCH INTERACTION IN JAPAN

SOGO OKAMURA

Director-General, Japan Society for the Promotion of Science, Tokyo

The rapid strides made by Japanese technology and industry gave the impression to many people that University-Industry interaction in Japan has been quite successful. This was, however, not so; systematic co-operation between universities and industry in Japan was still poor.

Dr Okamura dwelt on the reasons for this state of affairs and identified the barriers to this cooperation. One of the barriers was lack of information in both places. The Japan Society for Promotion of Science (JSPS) has been providing a forum for promoting cooperation between the universities and industry by creating industry-university cooperative research committees on specific themes where researchers from both industry and the universities meet and discuss recent research results.

Another barrier to university-industry interaction is the potential conflicts which exist between universities and industry. In general, university research is planned for long range objectives, while research in industry needs results by a definite deadline.

Dr Okamura described the steps being taken in Japan to strengthen the linkage between universities and industry.

The full text of the paper appears on page 84

GEOMEDICINE

J LÅG

President, Norwegian Academy of Sciences and Letters, Oslo.

The well known soil scientist dealt with the influence of environmental factors on the geographical distribution of problems of human and animal health. He discussed factors influencing chemical composition of soils in the light of recent Norwegian investigations and raised questions on basic data for characterizing the environmental factors. Some important questions relating to the circulation processes soil-plant-animal-man and back with waste material were still unsolved. Pollution problems of industrial and urban character caused further complications. To resolve these questions, Prof. Lag considered free exchange of information and ideas among scientists with different backgrounds. Close collaboration across traditional subject frontiers was necessary for the solution of many geomedical problems.

The full text of the paper appears on page 102

THE MAIN PROBLEMS OF ASIAN CONTINENT TECTONICS

A L YANSHIN *et al.*

Vice-President, USSR Academy of Sciences, Moscow

Professor Yanshin spoke on his favourite subject - the mechanism of formation of deep sea troughs located between the continents and on their margins - to which he has made significant contributions. His main focus was the tectonics of the continent of Asia and its complex geological history.

He said Asia is not only the most spacious of the continents but also the most complicated in structure. The greatest of the earth concentration of mountain ranges is in the centre of Asia, whereas the central parts of other continents are occupied by plains and highlands corresponding to all platforms. All these peculiarities speak of the complicated geological history of the Asian continent.

Quoting Soviet scientists Prof. Yanshin said, "India is moving towards North Soviet Union at 18-24 mm per year". So our two great countries come closer to each other not only economically and politically but geologically as well, Prof. Yanshin added.

A detailed report appears on page 113

SCIENCE, SCIENTISTS AND SOCIETY

ANNA J HARRISON

President, American Association for the Advancement of Science, Washington, DC

Dr Anna Harrison spoke of the rich resource offered by science, engineering and technology in the resolution of various societal issues. Some of these issues are global in character such as ozone in the stratosphere and carbon dioxide in the atmosphere. Others, such as malnutrition, epidemics, acid rain and the unequal distribution of wealth, manifest themselves locally and regionally but are widely prevalent. These also are world issues.

The knowledge generated by institutions and individuals should be placed in the public domain for the benefit of society. The magnitude of the benefits and the magnitude of the burdens of technology may be quite different. The challenge is to selectively use technology to enhance the quality of life and to equalize the distribution of benefits and burdens. This sweet-bitter characteristic of technological change is not peculier to technological change but is a characteristic of change of all social, economic and political change.

Societal issues have to do with the quality of life of this and succeeding generations. The decisions that must be made in the resolution of societal issues involve value judgements. Value judgements are shaped by the culture. Priorities within a culture must also be responsive to all social, economic and political pressures and to the abundance of both renewable and non-renewable resources. In response to such pressures, priorities may change quickly and significantly.

Concluding, Dr. Harrison declared that the ultimate goal was the expansion of knowledge and the use of knowledge to enhance the quality of life of this and succeeding generations. The pursuit of this goal can be, and should be, an exciting adventure.

The full text is reproduced on page 122

SCIENCE AND VALUES

D S KOTHARI

Chancellor, Jawaharlal Nehru University, New Delhi.

Eminent scientist, philosopher and educationist, Prof. Kothari in his learned lecture led the audience to the realm of ethical - moral values and their relevance in the pursuit of science, education and world peace. He observed, "Science and technology can tell us what can be done and what cannot be done". Science describes the limits of the possible. But science cannot tell us what we ought to do. That decision is an ethical-moral decision. Scientific truths and moral truths are not contradictory. *These are complementary.* It is the exploration and practice of the complementarity of scientific and moral truths that gives to life richness and beauty and happiness.

Referring to the teaching of science, Prof. Kothari said, "Science properly taught, can contribute much and effectively to the incorporation of the moral component in education - central to man's progress and even survival in Atomic age. The task is by no means easy : it demands sustained, imaginative and dedicated effort. The need is desparate. The Indian National Science Academy can make a significant and pioneering contribution. A basic element of education ought to be the theory and practice of how to subdue our *real enemies : Kama* and *Krodha* (greed, hatred and delusion). Nothing could be of greater value in life and for the welfare and progress of the community and mankind. How to make even a beginning in this direction needs intensive study and research.

Concluding Prof. Kothari said, "To man's great good fortune, science—perhaps unexpectedly is now slowly but steadfastly moving towards a more unified world view which includes both knowledge and values as complementary and mutually reinforcing. He called

upon scientists to cooperate with each other in strengthening the cause of world peace and global development.

A more detailed version of the lecture appears on page 129

RECIPIENTS OF GOLDEN JUBILEE PLAQUES AND MEDALS

FOUNDATION FELLOWS:

1. Prof S Chowla
2. Prof N R Dhar
3. Dr S Krishna
4. Dr G S Mahajani
5. Dr K R Ramanathan
6. Dr W D West

PAST PRESIDENTS:

Dr A N Khosla (1961-62)
Prof B R Seshachar (1971-72)
Prof D S Kothari (1973-74)
Dr B P Pal (1975-76)
Dr Raja Ramanna (1977-78)
Prof V Ramalingaswami (1979-80)
Prof M G K Menon (1981-82)

COLLABORATING SOCIETIES AND ACADEMIES IN INDIA:

Dr R K Pal (Asiatic Society, Calcutta)
Prof A S Paintal (Indian Science Congress Association)
Dr S Z Qasim (National Academy of Sciences, Allahabad)
Prof S Ramaseshan (Indian Academy of Sciences, Bangalore)

OVERSEAS ACADEMIES:

Prof Andre Blanc-Lapierre, (French Academy of Sciences)
Prof Erno Nemcez (Hungarian Academy of Sciences)
Dr Sogo Okamura (Japan Society for Promotion of Science)

Prof Jul Lag (Norwegian Academy of Sciences)
Prof Leonard Sosnowski (Polish Academy of Sciences)
Sir Andrew Huxley (The Royal Society, London)
Prof A L Yanshin (USSR Academy of Sciences)

ADHERING ORGANISATIONS:

Prof B Shah D Jalal (Afghanistan Academy of Sciences)
Prof Anna Harrison (American Association for the Advancement of Science)
Prof T P Feng (Chinese Academy of Sciences)
Dr Mahindra Giri (Royal Nepal Academy of Sciences)
Dr Karimullah (Pakistan Academy of Sciences)
Prof A N Rao (Singapore National Academy of Sciences)
Dr N D Wijesekera (National Academy of Sciences of Sri Lanka).

INSA GOLDEN JUBILEE PUBLICATIONS

PERSPECTIVE AND STATUS REPORTS

1. Nutrition and Brain — P N Tandon and G Gopinath.
2. Solid State Chemistry — C N R Rao
3. Liquid Crystals — S Chandrasekhar
4. Perspective in Organometallic Chemistry — R C Mehrotra and G Srivastava
5. The Monsoons: A Perspective — P K Das
6. Rice in 2000 A D — M S Swaminathan
7. Environmental Chemical Mutagenesis — Archana Sharma
8. Basic Building Blocks Began [. . .] Big Bang — A N Mitra
9. The Dharwar Craton — C S Pichamuthu and R Srinivasan
10. Perspective in Organic Synthesis — G Mehta and M Nagarajan.
11. Mathematical Models of Environment — J N Kapur

CONCLUDING SESSION

The historic event of the inauguration of the Golden Jubilee Year came to a close on the evening of January 18, 1984. Recalling the principal events of the celebrations and summarising the highlights of learned presentations by distinguished speakers during the preceding two days, including the initial Blackett Memorial Lecture by Sir Andrew Huxley, the President, Professor A K Sharma, expressed satisfaction at the success of the programme. The entire Fellowship of the Academy, including Foundation Fellows, Past Presidents, young scientists and others, had participated fully in the celebrations, ensuring its success. He stressed that the strength of the Academy lay in its Fellowship and in its academic programmes. This had been achieved not through a single step but through successive steps, following the policy guidelines laid down by the Foundation Fellows and successive Presidents, whose vision and foresight had raised the Academy to such a high level of excellence. He referred to his predecessors - Professor D S Kothari, Dr B P Pal, Dr Raja Ramanna, Professor V Ramalingaswamy and Professor M G K Menon - who had lent active support to the various facets of the jubilee programmes. The presence of two distinguished Foundation Fellows, Professor W D West and Dr K R Ramanathan was a great satisfaction to the entire Fellowship.

The formation of the Federation of Asian Scientific Academies and Societies (FASAS) on January 15, 1984 was a development of great significance in which several scientists had actively contributed in various ways. The President made special mention of Dr N D. Wijesekera (National Academy of Science of Sri Lanka) for his assistance in framing the constitution of the Federation and of the untiring efforts of Professor Y Nayudamma, Dr S Radhakrishna (COSTED) and Shri A K Bose (INSA). He expressed the hope that the Federation would help forge closer collaboration in solving urgent problems of the region through the sharing of experiences

among scientists from collaborating academies and societies.

Professor Sharma then warmly thanked the Indian and foreign academies and societies for participating actively in the celebrations. The Indian National Science Academy was indeed privileged to have their distinguished Presidents and representatives on this great occasion.

The President presented souvenirs to six of the oldest employees of INSA who had been in service of the Academy for 25 years or more.

The proceedings concluded with a General Body Meeting of the Fellowship of the Academy.

LECTURES AND PRESENTATIONS –
FULL TEXTS

WELCOME ADDRESS

PROF A K SHARMA

Madam Prime Minister, Professor Menon, distinguished scientists of Academies and Societies of different parts of the world, guests, Fellows, Your Excellencies and officers of the Academy, Ladies and Gentlemen – It is privilege for me to extend on behalf of the Academy and on my own behalf a hearty welcome to you all.

To you Madam, we are specially grateful for your presence on this historic event of the Golden Jubilee Celebrations of the Academy. May I take this opportunity to present before you the genesis of this event and the programmes to be undertaken to commemorate this occasion.

Indian science has a long antecedent period of evolution and has always been guided by a rational and philosophical approach. This tradition of analysis and examination as prerequisites for acceptance, embodied in concepts of Aryabhatta, Charaka Samhita and Sulbhasultras has been maintained even in the development of modern science and technology. This legacy of science and technology has been pursued in modern India since the inception of Asiatic Society at Calcutta in 1784, which led to the birth of Indian Science Congress Association in 1912 for disseminating the message of science to the masses. The establishment of National Institute of Sciences of India on 7 January 1935 at Calcutta was the outcome of a desire of having a peer body of scientists to discuss national issues, the idea being mooted at the Indian Science Congress in the previous year. The first meeting of our Academy, the then National Institute of Sciences of India, was presided over by Professor L.L. Fermour, a reputed geologist and who happened to be the President of the Indian Science Congress previous year. The charter of objectives of this august body includes the generation of knowledge, promotion of excellence, execution of programme of

national and international relevance, projection of science in the international forum and safeguarding the interests of scientists. The recognition of National Institute of Sciences as the Principal Science Academy representing all branches of science and technology was accepted by the Government in 1945 and the headquarters were moved to Delhi three years later, the foundation stone of the building being laid by Pandit Jawaharlal Nehru.

PRESENT ACTIVITIES

i) FELLOWSHIP

In order to fulfil its objectives of identifying excellence, the Academy selects 30 Fellows every year through 10 Sectional Committees having high level of scientific eminence, and the present strength stands at about little more than 500. The publication of peer reviewed journals on all branches of science, monographs on different issues both on technical aspects and national relevance, sponsoring of seminars and symposia, constitute certain facets of Academy's activities. Over and above the Fellowships, the Academy promotes and recognises excellence through medals and awards to various scientists of different disciplines including endowment lecturerships.

ii) YOUNG SCIENTIST PROGRAMME

Since 1969 one of the programmes of Indian National Science Academy has been the identification of young talent through selection of young scientists, awards being presented by the Prime Minister at the annual session of the Science Congress. This activity, leaving aside, the financial benefits and suitable grants for the research project for the selected scientists, has come to be recognized as the highest form of recognition, a young scientist can aspire to in this country. The success of this programme is reflected in the very fact that 80% of the young scientists have been able to secure a congenial atmosphere in pursuit of research in this country.

iii) INFORMATION DISSEMINATION

The dissemination of knowledge amongst scientific community in general is executed by the Academy through its publications, local chapters, and groups engaged in popularization of science.

iv) INTERNATIONAL PROGRAMMES

These are attended to by twenty-seven national committees of

the Academy in different facets of science and technology. As the adhering organization of International Council of Scientific Union on behalf of the Government of India, since 1968, it finances delegation to all international congresses and sponsors similar activities in India, the last one being International Congress of Genetics, held at New Delhi, last month. The Academy is privileged to have bilateral Inter Academy agreements for the pursuit of different scientific activities, with the Royal Society, London, USSR Academy of Sciences, Hungarian Academy of Sciences, Japan Society for the Promotion of Science, Norwegian Academy of Sciences, Polish Academy of Sciences, Philippine Academy of Sciences and the French Academy of Sciences, the last four being added last year. The success of the programme is indicated by the very fact that the financial input of the above project has been substantially increased from this year by the corresponding Acadamies, being reciprocated by INSA as well.

NEW PROGRAMMES IN THE GOLDEN JUBILEE YEAR

i) PUBLICATIONS

New activities have been initiated in the Golden Jubilee Year of the Academy to involve Fellowship to discharge their responsibilities in national and international context. For the Academy to participate in decision making issues of the Government, the Council has undertaken authoritative publications on topics of vital interest like Environment, Energy, Population control, Agriculture and others which would outline, the present state, limitations, suggested remedial measures, and projection for the future. In fact, several of the presidential addresses delivered by my predecessors laid the foundation of national policies in later years like River Valley Projects, Researches on Radio Science and Space, Policies for national laboratories and even the basic document of national planning. The recommendations emanating from earlier publications like basic sciences in relation to agriculture, flood disaster, rodent control, pesticide residues, have already been implemented by the Government. Over and above such issues dealing with science and society, perspective reports on different branches of science have been prepared by scientists of eminence in these fields to be released by our Prime Minister today.

ii) PROFESSORSHIPS AND FELLOWSHIPS

It is a pleasure for me to state that the recognition of high level of excellence and for their utilization, professorships have been instituted of which the first one, the Albert Einstein Professorship has been awarded to Professor G.N. Ramachandran a distinguished

Fellow of the Royal Society of London. These Professorships are tenable for a period of 5 years at the first instance comparable to that of the National Professorships. The objectives of optimum utilization of human knowledge and generating a base of excellence, are achieved through provision of Fellowships to talented scientists below the age of 40, at the institutions of their choice where infrastructure and atmosphere are conducive to their activities. Just as the Academy is devoted to cultivating excellence amongst younger generations, it has also been decided to utilize suitably the services of Fellows, active in research after their retirements, in the preparation of scientific documents, programmes and projects both of applied and basic nature.

iii) INTERNATIONAL COLLABORATION

One of the important developments at the international level undertaken by our Academy in the Golden Jubilee Year, is the collaboration with neighbouring countries of Asia to solve national vis a vis regional problems, ultimately aimed at the alleviation of human suffering without disturbing the natural ecosystem. With this aim in view, the idea of forming a federation was mooted by Presidents of Academies and Scientific Societies of neighbouring countries at a meeting held at INSA two months back. The meeting was organized with the assistance of COSTED (Committee of Science and Technology in Developing Countries). It is a pleasure for me to report that the formation of this federation was confirmed yesterday and an executive committee has been formed to steer the activities of the federation with representatives from ten countries. From the very first year itself it would initiate programme of holding workshops, demonstration of relevant technology, in different regions of Asia, depending on the expertise available in the country. This year two such workshops would be organized in India along with others. These programmes, if successful, would be a signal contribution of the Academies and Scientific Societies to solve regional problems through cooperative endeavour. This is in line with the desire you expressed Madam, in the meeting of Asian Foreign Ministers in August 1983.

iv) LIAISON WITH OTHER SOCIETIES

Indian National Science Academy, though a peer scientific body should not insulate itself from the general scientific stream of our country which represents third longest scientific manpower in the world. The Council has decided to involve different disciplinary societies of established reputation, and satisfying certain criteria laid down by the Academy, as adhering organizations, for their joint activities in relation to issues of national importance and other

technical discussion. Liaison with State Academies and Scientific Societies would be maintained by our Academy providing necessary facilities for the meetings and different programmes and suitable arrangements for the accommodation of the scientists. This would lead to a close involvement of the Academy with the general scientific community, thus helping in generating a broad base of good level of science on the one hand, and excellence on the other.

v) BUILDING

The expanding programmes of the Academy including liaison with different societies in India, need adequate space for which a science complex building is proposed to be constructed at the premises of the Academy on its western side. The initial donation for this building amounting to rupees ten lakhs has been made by Dr Biren Roy, a noted aeronautical engineer of Calcutta, a great social worker, former Member of the Parliament and a close associate of the leaders of national movement before independence. Substantial donations have also been received from Departments of Environment, Science and Technology, Ocean Development, Atomic Engery, Space Research and Council of Scientific and Industrial Research.

vi) EXCELLENCE IN SCIENCE

A few words are needed on this occasion with regard to promotion of excellence in science. It is one of the most vital issues affecting the very fabric of our scientific endeavour and has been extensively discussed in the Scientific Advisory Committee to the Cabinet, in our Academy, as well as in the last Science Congress. If one compares the renaissance period of Science in India, characterised by outstanding luminaries like Raman, Ramanujam, Saha, Bose, Sahni and others with the present era, an introspection is called for in spite of the fact that a broad base of science and technology had been created. Of the different measures recommended so far for the culture of excellence and elevate the status of science in this country, it is true, that repatriation of scientists working abroad is often suggested. Their repatriation undoubtedly may open facets of research which may pay high dividends in future. But the Academy is deeply concerned about scientists, both young and old who are striving hard in Indian situation to make a mark in science. The promotion of creativity, provision of a congenial atmosphere free from bureaucracy for the pursuit of excellence, of such undrained brain, is of paramount importance to our Academy.

vii) AUTONOMY OF INSA

Lastly, I may be permitted to say a few words on the autonomy of the Indian National Science Academy. It is undoubtedly an autonomous organization, the supreme scientific non governmental body in the country and the adhering organization of the International Council of Scientific Union on behalf of the Government of India. It stands for promotion of excellence, generation of a wide base of scientific knowledge, projection of science in international forum and helping the Government on issues of national relevance. For the expanding activities and to fulfil the character of its objectives, it requires financial independence as well. The grant at present allocated to the Academy is inadequate to support all its activities. Our Government is committed to the culture of excellence on the one hand, and generation of a base of science and technology on the other, which is enshrined in our constitution and the remarkable science policy resolution. It is indeed paradoxical that INSA which is an emblem of excellence in the country, is striving hard to obtain financial assistance to expand its activities. The Academy is fully aware of that limitations under which the Department of Science and Technology has to function within its limited resources. It is therefore desirable that the allocation for this Academy is decided separately at the highest national level for financing by the Department of Science and Technology and be adequate to maintain its activities with all its programmes including Golden Jubilee Celebrations and the science complex. On behalf of the Fellowship, I have the privilege of expressing our hope to you, Madam, that the Academy be permitted to meet not merely its financial need for the present, but be given the status which as the supreme scientific organization in the country, it deserves and demands. It is not only vital for science but also vital for the development of the nation.

Thank you for your kind and patient hearing.

INAUGURAL ADDRESS

INDIRA GANDHI

In recent weeks, I have addressed several gatherings of scientists but this occasion is something special. It is the Golden Jubilee of an organisation recognised as "the premier society representing all branches of science in India." The INSA is also entrusted with responsibility for our country's international scientific relationship.

The word "academic" is used for scholarship in general. But the noun Academy connotes intellectual achievement of high excellence, recalling the garden where Plato taught. Soon after Independence, three academies were established in our country, under the inspiration of my father and that savant, Maulana Azad, to promote creativity, excellence and greater awareness of literature, music and drama and the fine arts. Your Academy was started by pioneering scientists much before we became free, and at a time when the alien Government was not too enthusiastic about Indian science. So were two other organisations of scientists — the National Academy of Sciences and the Indian Academy of Sciences.

There is a provocative statement, "Art is I, Science is We", suggesting that art is an individual pursuit and science a corporate one. Poetry is said to be the product of a person's quarrel with himself. Science is the outcome of intellectual confrontation with the Universe. However, I doubt if artists are such lone wolves as they are made out to be. Had they been so, we would not have the various movements in art and literature and such numerous styles and schools. Also, in science no less than in art, does the lightning of insight and revelation strike the individual in his innermost

recesses. Nor is science less concerned with beauty.

Because science grows by refutation, discussion and open scrutiny by fellow-workers, societies and academies do have special place in the advancement of science. Professional societies are as old as the emergence of modern science. The Royal Society of London, regarded as the oldest of them was established in 1660, but a nucleus had existed for several years before. Sir Robert Boyle has written about an "invisible college" which held weekly meetings in 1646-47 of "diverse persons, inquisitive into natural philosophy and other parts of human learning, particularly of what has been called the New Philosophy or Experimental Philosophy". The French and Italian Academies of Sciences are other examples of institutions which have fostered observation, discovery and the exposition of theories, and have published journals and records. In the Soviet Union and other socialist countries, Academies of science are entrusted also with executive responsibilities. They administer large scientific enterprises, including chains of laboratories and major projects.

In our age of growing and perhaps excessive, specialisation, leaders in different fields should come together to consider the larger problems of science. An Academy gives them the opportunity of doing so. Division of knowledge into various fields is an artificial convenience. More and more it is being realised that the demarcating lines are not so clear cut. That is why any number of new branches of study have come up with hypenated names. In Eastern civilizations, knowledge has always been regarded as one, but Western science is only recently becoming increasingly multidisciplinary. Cross fertilisation is inescapable. In our own country and elsewhere we see that any rigidity of thinking leads to stagnancy. Growth needs mobility. For the best of human beings, life is not scarred by narrow sectional walls.

Scientists are citizens enjoying high prestige. Society has many expectations of them. Many major national decisions are guided by their opinions — matters of development, defence and education, and for us the entire endeavour of remedying the injustices of the past and preparing for the future.

Our Science Policy Resolution, which Jawaharlal Nehru formulated, sets forth the role of science in promoting prosperity and conserving capital and in the diffusion of culture to all sections of our people. He felt that a country of India's great cultural heritage had an obligation to participate fully in the march of science and that without science we could not solve our problems of hunger and

poverty. He said that the future was with those who made friends with science.

The Golden Jubilee of your Academy comes within a year of the silver jubilee of the Science Policy Resolution. I should like the Academy to examine to what extent science and technology in India have been decisive agents of dynamic and beneficial change. Every institution must renew itself and be constantly thinking of its work in the future. Members of the Academy, so much more than others, are in a position to understand the implications of the development in science, to educate public opinion and to advise Government.

In several areas of scientific and technological activity, we must have close goals in order to get the best out of funds, manpower and equipment, specially when these are so scarce. But the progress of knowledge cannot be made to order. It is said that technology must always be useful, whereas science need not. But what is regarded as useless or too expensive today, may be useful and comparatively less costly tomorrow. Many great applications are unpremeditated off-shoots of altogether different quests. Like Columbus, many scientists journeyed to find one country and reached another.

Scientists have to set their own goals in research, but, as President Kennedy observed, in extending support to science, society must take its own needs into account. In India we have fully involved scientists in policy making. We have asked them to address themselves to the most urgent national needs. The greatest of these is the generation of more employment and higher incomes in our villages, by disseminating new knowledge and improved methods of productivity. Not long ago, our farmers distrusted agricultural scientists, thinking that they lacked practical knowledge and experience in the field. People also kept away from hospitals. Fortunately, that phase is over even though there is no dearth of persons gullible enough to be misled by false propaganda, often to their own harm. On the whole, people are eager to benefit from modern knowledge, whether it be to raise greater yields from their fields or to better cure their ailments.

Rural India thirsts for science. Rural India has immense potential for scientists to use what is available not only in human talent but in the material that is found in the plant life or in the talents of the people. Our scientists must respond to these needs. I don't want to restrict their work in other fields, far from it; but unless some people, some scientists look to the immediate and use what is available, it will be more difficult for science in the higher reaches. Today we have very eminent scientists, some of whom you have seen and others whom you have not; but they are just the tip

of a tree and unless the trunk and the roots of that tree are strengthened, it is more difficult to produce larger number of scientists and other people who can take the entire country forward as well as add to universal knowledge. I am glad that some of our scientists young and old, are studying rural problems, unglamorous though this may sometimes seem. I hope their number will grow. We want them to increasingly concern themselves with economic, social and cultural advancement of our country. But their responsibility does not end there. Scientists everywhere are also directly concerned with the problems of war and peace. Science has to believe the charge that it has led to the brutalisation of human beings.

There are many divisions in our world. The most glaring is the disparity between the technologically developed and developing. The growth of science is said to be exponential. I wonder if we can ever close this gap? Science and technology have become the means for economic power and also for military power. In an unequal world they are forces for domination and exploitation. The only way to avoid this is through the development of indigenous capabilities in science and technology in all communities and in all parts of the world, and through growing international cooperation in science. Self-reliance is good for every country, but for a country of our size and circumstances it is indispensable. It is the only basis on which there can be non-exploitative international cooperation. We can participate in such cooperation only to the extent that we are able to adapt and assimilate what we need from outside, while striving for original ideas and work ourselves.

The guidance that we seek from science is how to enable men and women to use their own capacities and inner resources to the utmost.

May your Academy set the highest standards of professional conduct and of intellectual and moral responsibility.

I congratulate you on your Golden Jubilee and I have great pleasure in inaugurating your celebrations and to specially those who have come from abroad, may I give my very warm greetings and I hope that your discussions here will be helpful to us all and that your stay in our country will be interesting and enjoyable.

e Prime Minister is escorted by Prof. A K Sharma (President) and Prof. M G K
enon as she arrives to inaugurate the Golden Jubilee Celebrations

A view of the dais at the Inaugural Function on 16 January 1984

At the inaugural function: the Prime Minister flanked by Prof. A K Sharma and Prof M G K Menon

"Eighty per cent of young scientist awardees under the Academy's activity of identifying young talent have secured a congenial atmosphere in pursuit of research within the country" – Prof. A K Sharma while delivering his Welcome Address

A model of the Science Complex Building was unveiled by the Prime Minister. The building will provide room for the expanding national and international activities of the Academy

On behalf of the Fellowship, the Academy President, Prof. Sharma presented a Souvenir to the Prime Minister as a mark of appreciation of her sustained interest in and continued support to the cause of science in India

Releasing the Golden Jubilee Publications

Past Presidents and Foundation Fellows of INSA receive Jubilee Plaques and Medals from the Prime Minister

Past President **Dr B P Pal**

Prof D S Kothari

Dr Raja Ramanna

Dr V Ramalingaswami

Prof. M G K Menon

The Torch Bearers: Foundation Fellows Dr K R Ramanathan and Dr W D West (Bottom)

This occasion is something special — the Golden Jubilee of an organization
ecognized as the premier society representing all branches of science in India" —
rime Minister Indira Gandhi delivering her Inaugural Address

Prof. M G K Menon proposing a vote of thanks.

A section of the august audience including overseas guests.

nhommie: the Prime Minister with the guests.

The birth of FASAS: the Consultative Committee at its meeting on 15 anuary 1984 decided to constitute the Federation of Asian Scientific Academies and Societies.

The Fellowship

FIFTH BLACKETT MEMORIAL LECTURE*

SCIENCE AND POLITICS

SIR ANDREW HUXLEY OM, PRS

Let me say first what an honour and pleasure it is to me to be invited to deliver this Blackett Memorial Lecture, both by way of contributing to the Golden Jubilee Celebrations of your Academy, on which I congratulate you most warmly, and as an opportunity of paying homage to Lord Blackett. I worked under Blackett for two periods during the Second World War and it was impossible to be in contact with him without admiring him and being influenced by him.

LORD BLACKETT

Blackett was an outstanding scientist with a quite exceptional range of interests. Between the two World Wars he made numerous contributions to particle physics, chiefly by the study of cosmic rays, culminating in a clear demonstration of the existence of the positron. After World War II, he made investigations into the nature of magnetism, suspecting a direct relationship between angular momentum and magnetic moment. He was able to disprove this proposition and he then turned to geomagnetism and provided evidence for continental drift. In all these contributions to physics, Blackett combined to an unusual degree the skills of an experimental physicist with deep theoretical insight. This is something that struck his contemporaries as quite

* *Delivered on 17 January 1984 at the Indian National Science Academy, New Delhi*

exceptional, and it was recognised in the citation for the Nobel Prize, which he received in 1948. This was awarded for "his development of the Wilson method [the cloud chamber] and his discoveries, made by this method in nuclear physics and on cosmic radiation". He designed his own equipment, and to a large extent built it with his own hands. His automatically-controlled cloud chamber made possible his investigations of cosmic rays, and it was a magnetometer of unprecedented sensitivity developed by him after World War II that made possible his investigation of the nature of magnetism itself and, later, of the magnetisation of rocks.

Among British scientists of their generation, two of those who were most deeply concerned for India were Blackett himself and the physiologist AV Hill. Hill spent several months in India towards the end of World War II advising on the post-war development of science in India, and he visited India many times after the war, just as Blackett did. It is a coincidence that it was through Hill's influence that I came to work under Blackett. Hill had been the leader of the team of scientists who developed the methods of anti-aircraft gunnery during the 1914-18 war; in 1940 he recognised that Anti-Aircraft Command needed scientific advice and he introuduced Blackett to the Commander-in-Chief, General Pile, with the outcome that Blackett was soon appointed as his Scientific Adviser. Hill then proceeded to provide Blackett with a scientific staff; all our physical scientists were already engaged in the war effort but there were biologists who had not yet been drawn in, so Hill recruited first Leonard Bayliss, a colleague of his in the Physiology Department of University College London; then his own son David Hill, who was also a physiologist, and then myself, yet another physiologist, who had become a close friend of David's at college and had met Hill through that connection.

Blackett was an inspiring leader. He would see his way immediately to the heart of a problem, and had the confidence in his own judgement that enabled him to press his views at high level.
He was at that time already familiar both with radar and with air defence problems generally, through membership before the war of the Committee for the Scientific Survey of Air Defence, which had been responsible for giving to radar priority which ensured that it became operational in time for World War II, while

the problems of adapting the gun-control equipment to accept the rather unprecise data from radar sets were similar to the problems that he had solved in the design of aircraft bomb sites during the first year of the war, when he was working at the Royal Aircraft Establishment. The fact that he had started his career in the Navy, and had served as a midshipman in the battles of the Falkland Islands in 1914 and Jutland in 1916 helped to gain for him the confidence of senior officers. One way or another, this was an appointment for which he was ideally equipped, but after a successful period of a few months he was moved to Coastal Command of the Royal Air Force to apply his skills to a problem that had become more urgent than bombing attacks: the sinking of our supply ships by German submarines. He moved again in January 1942 to the Admiralty to become Chief Adviser of Operational Research (later Director of Naval Operational Research), and he got me transferred to become a member of his new team. He himself continued to concentrate on anti-submarine warfare but I was put to work in the Gunnery Division of the Naval Staff, so I did not see a great deal of him during this second period when I was under him.

It is appropriate that a Blackett Lecture should be devoted to 'Science and Politics' since Blackett divided his immense energy between these two spheres of human activity. From early in his life, he felt intensely, and with personal sympathy, the contrast between rich and poor, whether this showed up in the class distinction between officers and ratings in the Navy, in the plight of the unemployed during the depression of the thirties, or in the differences in living standards between Western nations and the developing world, especially India. Like JBS Haldane, another left-wing scientist of that generation who became deeply devoted to India, he was apt to be high-handed in his relations with academic colleagues but was exceptionally considerate towards his technical staff. He never stood for Parliament, though asked to do so as a Labour candidate in 1922, and he did not become a member of the House of Lords until 1969, when his political activity was more or less over; his political influence came through his books, through membership of high-level committees, and as adviser both personally to Harold Wilson and to the Ministry of Technology when it was formed in 1964 at the beginning of Wilson's first administration. He described himself as a Fabian socialist (i.e. a gradualist), though he was probably further to the left

than most of those who would use that designation. He was fully active in the war effort, at the highest levels of advice, in the period when the Hitler-Stalin pact was in force and many of those sympathised with Russian communism refused to support Britain against Germany. He consistently opposed the bombing of open cities. From shortly after the war, he was distrusted by both sides in national politics on account of his outspoken opposition to nuclear weapons, and for this reason his advice on either defence or civil matters was not available to the first post-war Labour government under Attlee.

BLACKETT AND THE DEVELOPING WORLD

This temporary eclipse of Blackett's participation in policy-making in Britain coincided with the start of his involvement with the problems of the developing world. This was triggered by his first visit to India, in January 1947, to take part in the first post-war meeting of the Indian Science Congress Association. He met Jawaharlal Nehru, who soon invited him to India again to advise on the research and development needs of the armed forces. He made numerous visits to India during the following twenty years, in connection with all aspects of science in India. In recognition of these services he was made an Honorary Fellow of the Indian Academy of Sciences, of the Indian National Science Academy and of the Tata Institute, and he received the honorary D.Sc. of the University of Delhi. But in addition to his direct concern with and help for India, his first visit to this country in 1947 opened his eyes to the world problems arising from the great, and increasing, disparity between the living standards of the industrially advanced nations and of what is now called the 'Third World'. His presidential address to the British Assòciation in 1957, and many subsequent lecturers, were devoted to this problem and to urging that the wealthy nations should contribute much larger sums by way of aid to the third world.

As regards our work in our respective scientific fields, I sup-
pose there are resemblances between myself and Blackett. Like 46
him, I have designed much of the apparatus I have used, and in-
deed each of us constructed a good deal of it ourselves. Like him
again, I have also been a theorist, though in a field where theory is
of much more elementary kind than in his. But he had much
broader horizons than I, and I make no claim to parallel him in ei-

ther the breadth or the intensity of his involvement in social and political matters. Nevertheless, I have found myself in the position of President of the Royal Society, which Blackett held from 1965 to 1970, and this has brought me into immediate contact with matters on which science and politics interact with each other.

SCIENCE AND POLITICS

Just as there are analogies between Science and Art, for instance in the importance that scientists commonly give to elegance or style in their work, so there are analogies between Science and Politics. R A Butler, who at different times held most of the important posts in British cabinets except that of Prime Minister, gave to his autobiography the title "The Art of the Posssible", using this as a synonym for politics. And Sir Peter Medawar entitled one of his books of scientific essays, "The Art of the Soluble", with reference to the activity of a scientist. Both the scientist and the politician are faced by problems of great difficulty, and one of the conditions of success for either is that he should recognise which of those problems he has a chance of solving. I am very clear that the problems I have attacked are not the most important problems in biology, such as the genetic code or the control of growth and development; I have found myself working on nerve and on muscle partly through personal chance - as regards nerve, the opportunity to work with Alan Hodgkin - and partly through recognising that my training and my ways of thought fitted me to make some progress in fields of biology where the events to be studied are of a physical character - electrical, optical or mechanical. To say that science is the art of the soluble is a statement, not a definition, and this is likewise the case if one says that politics is the art of the possible. These are statements about the kinds of skills needed in these two kinds of human activity, but actual definitions have to be given in terms not of method but of purpose, or aim. Politics is the art of managing people by persuation; when I am feeling cynical, I say that it is the craft of persuading other people to act in one's own interest. Science, on the other hand, is the systematic effort to understand and to control Nature, using experiment and observation to check one's ideas. Looked at in this way, from the point of view of aim rather than method, there is no resemblance between them.

BASIC AND APPLIED SCIENCE: A DISTINCTION OF PURPOSE

The distinction between "pure" or "basic" science on the one hand, and "applied" science on the other, is of the same kind. Many scientists will say that this distinction does not exist. The methods are the same; often the same individuals pursue both kinds of science at different times; both depend on the same background of scientific knowledge; a particular discovery may result from the pursuit of either pure or applied science; one piece of research may be regarded as "pure" by one person but "applied" by another; and both can be equally satisfying to their practitioners. The distinction is not a sharp one, but it is a common fallacy to argue that because a distinction is not sharp, therefore it does not exist: we all know that it is useful to name the colours of the spectrum although each merges into the next by insensible gradations as the wavelength is changed.

But in spite of all these resemblances between "pure" and "applied" science, and in spite of difficulties in making the distinction, it is clear to me that a real distinction does exist, and that it is an important one. Like the distinction between science itself and politics, it is a distinction of purpose or aim. The scientist's aim in pure science is to improve our understanding of nature; in applied science it is to achieve some useful goal - to build a machine, to cure a disease, or whatever it may be. Much of the objection that is raised to making this distinction is that a substantial part of the work actually done by scientists can be said to fall into both of the categories so defined. This fact makes it necessary to define a third, intermediate, category, for which perhaps the most apposite name is "strategic research", a phrase introduced by Sir Frederick Dainton. The usual way of defining strategic research is to say that it is research which is basic in character but has a recognisable prospect of leading ultimately to practical application and which is carried out with this purpose in view. I prefer a different, but equivalent, definition, namely that it is research which is pure from the point of view of the investigator himself but applied from the point of view of his employer. 48

The distinction between these three categories of scientific research - pure, strategic and applied - are of course not perfectly sharp, but I believe that classifying research in this way is not likely to be seriously misleading. Some such classification is neces-

sary for any discussion of the relations between science and politics because the politician quite rightly regards these three divisions of science in different ways.

GOVERNMENT SUPPORT OF SCIENCE

Politicians and scientists have ambivalent feelings towards each other. The scientist needs money from his Government, but he does not wish to be told what problem to work on, and often claims that academic freedom is an absolute right which entitles him to pursue his own interests irrespective of all other considerations. He wishes his discoveries to be used but does not like to have his efforts directed into channels that seem likely to be useful.

The politician is glad of the international prestige that is won by discoveries in pure science but - in some regimes at least - he distrusts the scientist on account of the international character of his outlook. He recognises the economic and social importance of applied science, but as one progresses through strategic to pure science, the time scale of any practical outcome become longer and is soon beyond the range of interest of those politicians whose horizon is set by the next election. Research is essentially the exploration of the unknown, and the resulting unpredictability of its outcome makes it impossible to guarantee economic benefit from strategic or pure research, and the expenditure they require is correspondingly more difficult to justify. The intellectual importance of an improved understanding of Nature is immense, as will be recognised as soon as one considers the changes of outlook brought about by the progress of science in the last few centuries, but these changes are taken for granted by most of us and the politician does not attract votes by defending expenditure on pure science on these grounds. In fact, all the pressures on the politician are such as to make him think in terms only of those kinds of scientific research that have a forseeable outcome in economic benefit. When Mr Heath was Prime Minister, he called together a number of scientists, mostly from academic life, for a general discussion on policy for science, and much of the discussions was at cross purposes because when Mr.Heath used the word "science" he meant applied science but he was given replies that were relevant to pure science.

No country except the USA is large enough and rich enough to attempt to stay near the forefront of scientific advance in every field; less rich countries must either pool their resources or restrict the range of their contributions, and must rely on other countries to provide some of the 'pure science' which underlies all the practical applications. One of the difficult political judgements that every country has to make about the support of science. is how much effort the country can afford to put into the advance of "pure science". This advance is an international process to which most countries can only make a limited contribution, and there is a temptation to take the easy way out of letting the fundamental science be done by countries wealtheir than one's own and hoping to cash in by taking up the discoveries made abroad and making use of them in one's own industrial development. The widely-recognised flaw in this approach is that a country which has no original research in a particular field is unlikely to recognise a potentially useful advance in that field quickly enough to avoid being forestalled in its application. As in every political problem, the difficulty is that there is no rigorous way of working out what is the right balance - in this case, between on the one hand, putting an excessive share of the available scientific effort into work whose practical outcome, if any, will be in the distant future, and on the other hand, not having the capability of taking advantage of unforeseen advances that are made in other countries.

This problem is no doubt most acute in the developing world, but it exists in every country, and it causes much heart-searching in Britain at the present time. The present government, in one sense quite rightly, gives first priority to the regeneration of our industry, so as to provide the wealth on which everything else depends, including the pursuit of science. An increasing proportion of our "Science Budget" is being used for applied science, leaving a falling sum for our contribution to the advance of understanding of the natural world. It is only by collaboration with other countries, especially within Europe, that we have been able to continue taking a part in the "big science" that requires particle 50
accelerators, telescopes, satellites and so forth. Even so, these joint projects are taking an uncomfortably large share of the funds provided for fundamental research, especially when changes in exchange rates make them become more expensive in terms of sterling.

It is being said on every side - and I believe it is substantially true - that in recent decades Britain has, for her size, been very successful in pure science but has lagged behind her cheif industrial competitors in putting new discoveries to practical use. A contributory factor in this trend has been the prestige that the pursuit of science, as opposed to industry, has been given in Britain. Among my contemporaries reading science at Cambridge just before World War II, there were very few whose ambition was to work in industry. This tendency continued after the war, though there are hints that it may be changing now. It must be true that our industry would benefit if it were able to attract a higher proportion of the best of our scientifically trained man-power, and this can be used as an argument for reducing the support of pure science so as to squeeze scientists out of pure and into strategic or applied research. One major danger in such a policy is that the really bright young scientist with an engrossing interest in pure science will emigrate rather than switch into a kind of work which he believes will be uncongenial. I say "believes" deliberately, because it often happens that when a scientist takes the plunge and moves out of academic life into industry, he finds the change a stimulating one: he has a better-defined objective to work for, and usually has more funds at his disposal. But even if this perhaps too rosy picture of industrial science has a substantial element of truth, it is what the scientist supposes that willl govern his decisions. Emigration of scientists from Britain - principally of course to the US - is not on a large scale at the present time, but it is enough to cause alarm especially in a few rapidly-developing fields such as biotechnology. More important, I suspect that a substantial element among the causes of our recent industrial weakness is the "brain drain" of scientists, and especially engineers, that took place twenty years or so ago, when the urgent development of space navigation in the USA, after the USSR put up the first artificial satellite, created an immense demand for applied scientists and drew away many of the brightest members of the generation from which the leading figures in the engineering industry of the present day are drawn.

I have dwelt on the problems in Britain, partly because I am familiar with them, but also because they are shared by other countries and particularly by the countries of the developing world. The question how much effort to allocate to pure science is more acute the smaller a country's pool of trained scientists and

the smaller its gross national product per head of population: indeed, a point comes where the support of truly pure science cannot be justified at all and the question becomes transformed into how much strategic, as opposed to applied, research can be afforded. The problem of emigration, too is more acute. My feelings on this are mixed: there is an element of pride that a richer country can offer opportunities to gifted individuals from a poorer, but there is a larger element of shame that we should be drawing off a substantial proportion of each generation of trained personnel that countries like India and Pakistan produce. I have felt this most strongly in relation to medicine; in our health service in Britain we have had to depend heavily on immigrant doctors, largely as a result of underestimating the numbers that we needed to train in our own medical schools.

Like every problem of the developing world, this one is exacerbated by the growth of population. Wealth that might be used for improving living standards or for the support of science with long-term benefits has to be used in the effort to maintain the existing standard for an increasing number of people. Each generation of professional people will have to serve a population perhaps twice as large as that from which it was drawn. Britain passed through this phase of rapid population growth in the 18th and 19th centuries, and it was accompanied by great poverty, but in recent decades our population has stayed nearly steady, and we have been able to put our effort into the improvement of living standards.

ADVISING THE GOVERNMENT

So far, I have been speaking of the political aspects of the financial support of science. A different set of considerations becomes important when scientists are asked - or offer - to give advice to their government. This is one of the important duties of a body such as the Royal Society. We are regularly asked to give our views to Royal Committees of either of the Houses of Parliament, and to many other official and unofficial bodies. I suppose that this is a function performed for every country by its central scientific academy, though the scale on which it is done varies over a wide range. The Royal Society is fairly active in this respect but we cannot claim to be in the same league as the National Academy of Sciences of the USA, which was established with the ex-

plicit duty of responding to every technical question put to it by the Federal Government, and which produces three or four hundred reports per year.

So long as the advice is restricted to questions of a technical nature, there are no problems of a moral kind about giving it. But all too often the questions on which advice is wanted are only partly technical and are partly, or even wholly, of a political character, in the sense that any solution will favour one section of the population against another. The scientist must then resist the temptation to go outside the field within which he is expert. If he does, he has no claim for his views to be given more weight then those of a layman - in many cases his views may deserve less weight since he is less practised in dealing with the unpredictable failing of human beings than say a business man or a lawyer. If he steps outside the range within which he has a real claim to special attention, he will forfeit his credibility for the future.

The difficulty of keeping technical and political questions separate is illustrated by an example from just 200 years ago. Though we rightly think of Benjamin Franklin as an American, he was elected a Fellow of the Royal Society in 1756, twenty years before the Declaration of Independence, and indeed he served many times on committees of the Royal Society. One subject on which he gave advice was the application of his own invention, the lightning conductor. He recommended that lightning conductors should be pointed, but there was a contrary view according to which pointed lightning conductors would attract a stroke of lightning and that it was safer to use rounded ones. Repeatedly, the Royal Society's committees found in favour of Franklin's opinion and they recommended accordingly that Government buildings should be equipped with pointed conductors. It is difficult to imagine a more purely technical question, but nevertheless it did acquire a political dimension. During the War of Independence, it came to be said that it was unpatriotic to favour pointed conductors because they were favoured by Franklin, who sided with the revolutionaries. The King changed the lightning conductors on his palaces from pointed to round, and he tried to persuade the Royal Society to reverse its advice. But I am glad to say that it stood firm, and it is recorded that the President, Sir John Pringle, replied to the King that duty as well as inclination would always induce him to execute his Majesty's wishes to the utmost

power; but, "Sire" said he, "I cannot reverse the laws and operations of nature."*

Among present-day problems, one on which the Royal Society has more than once been pressed to take up a conspicuous position is that of nuclear war. This is an example of the impossibility of separating the technical from the political aspects. Even the attempt to inform the public about the extent of devastation that a nuclear attact might cause – prima facie a purely technical matter – would acquire a political dimension in that the assumptions that are made about the scale of attack will determine whether the calculated outcome tends to favour the idea that a nuclear attack could be survived or that it must inevitably be totally devastating in its effects. It is perhaps fortunate for all national scientific societies that an investigation of these problems is now being carried out by SCOPE (Scientific Committee on Problems of the Environment), one of the committees of the International Council of Scientific Unions. Representatives of both East and West are taking part, and as far as is humanly possible the conclusions will be unbiassed and reliable. The Royal Society is making a very considerable contribution to the work of this committee.

Another current example is the problem of acid rain – as much an international problem as that of nuclear war though its potential effects are less horrifying. In this case, the Royal Society has recently taken on the chief responsibility, together with the academies of Norway and Sweden, for an investigation of the acidification of lakes in Scandinavia. This is of course attributed to emissions of sulphur dioxide etc. from the industrial countries to the south and south-west of Scandinavia, but the chemical processes in the air and on the ground that lead to this result are not yet understood, and there is consequently a real danger that enormous sums of money may be spent on ineffective precautions. The Central Electricity Generating Board and the National Coal Board are the bodies in Britain that stand to be most affected by the outcome of such investigations and they have the resources to carry them out; but if they were to fund the research 54
directly they would be accused of introducing bias. They have therefore entrusted considerable sums to the Royal Society and the Norwegian and Swedish Academies to carry out the investi-

* *A History of the Royal Society by R.C. Weld (1848) Vol. 2, p 101 London: John W. Parker*

gations, and the reputations of these bodies, together with their lack of financial interest in the outcome, guarantee that the investigation will be as nearly as possible unbiassed.

Most scientific academies, including the Royal Society, repeatedly become involved in questions of the treatment of scientists who have fallen foul of the regimes — whether of the right or of the left — of the countries in which they live. The moral issue is clear if a scientist is persecuted for his scientific opinions or if he is prevented from pursuing his chosen line of work because of supposed political implications. But it becomes less clear when a scientist is persecuted for political activities which are not directly connected with science: are we entitled to claim for scientists any greater freedom from political restraints than for other people? And the questions become even more difficult when the case of some scientist is taken up and used as a weapon for international propaganda.

KEEPING INDEPENDENCE

These are examples of the many tight-ropes along which scientific academies have to walk. Another, perhaps the most important of all, is the need to keep independence. Without funds from its Government, an academy cannot achieve much, but if it is wholly dependent on Government funds it is unable to express opinions unfavourable to its Government or contrary to Government policy. The Royal Society is in a fortunate position: we do receive several million pounds per annum from the Government, which we spend in direct support of research workers and on many international scientific activities, but we also have substantial private endowments which give us the independence that an academy needs. Our position is much more satisfactory than that of academies who do not have enough funds to operate on a useful scale, and it is also more satisfactory than those which, like the USSR Academy of Sciences, combine the functions of an academy with those of Research Councils and handle huge sums of Government money; they have effectively become branches of Government and no longer possess the freedom that an academy should have to speak on behalf of scientists.

A final mention of Lord Blackett is relevant in this connection. At one time, shortly after World War II, he was in favour of

the Royal Society becoming the major channel for Government funding of science in Britain. I think we are fortunate that this did not happen, and that instead the Research Council system was expanded for running scientific institutes, and for awarding research grants from Government money. Later, Blackett, appreciating the extent to which freedom of action depends on financial independence, led an appeal for additional endowment from industrial and charitable sources, which is one of the foundations of our present satisfactory position. This is one more example of his many-sided contributions to science. Thank you again for giving me this opportunity of reminding you of a few of the many things that he achieved.

SOME APPLICATIONS OF SIGNAL PROCESSING IN SPACE AND MEDICAL TECHNIQUES

A BLANC-LAPIERRE

Vice-President, French Academy of Sciences, Paris

The purpose of this talk is to give an outline on some recent applications of signal processing techniques to domains as different as spatial communications or medical imaging. It is more in the nature of a general survey than a specialist presentation.

The topic is considered in three parts:

I. Reviews of some basic concepts or properties in signal processing
II. Transmission of information over long distances, with an application to the deep space probes
III. Multidimensional imaging with application to medical imaging

I. SOME BASIC CONCEPTS OR PROPERTIES IN SIGNAL PROCESSING

The aim of signal processing techniques is to allow a better knowledge of some useful and interesting signal, starting from a set of experimental data, involving this signal, but contaminated by random or non random errors resulting from various distortion and noise effects.

In some cases, the purpose is the exact recovery of the signal, for instance, a time function. This is the situation in telecommunication problems.

In other cases, one only wants to know whether one specified signal exists or not. This is the case of the Radar and the Sonar, involved in alarm problems. It is, then, a problem of detection.

The following is devoted to problems of the first kind, that is to say devoted to the correct transmission of signal, or, speaking in a little different manner, to problems of information rate through one given communication channel.

The recent evolution of signal processing techniques is chiefly dominated by:
– the sampling of signals,
– the computerized numerical processing (quantized and digitalised signals),
– the fact that the signal processing problems must be considered in a global manner, that is to say, taking into account the transmission device as a whole:

$$\boxed{\text{Source}} \rightarrow \boxed{\text{Transmitter}} \rightarrow \boxed{\text{Channel}} \rightarrow \boxed{\text{Receiver}} \rightarrow \boxed{\text{Use}}$$

I. 1. SHANNON'S THEOREM (TIME SIGNALS)

Let $X(t)$ and $X(t_n)$ $(t_n = n\Theta)$ $(n = -\infty, \ldots, -1, 0, 1, \ldots)$ be the signal & its samples.The exponential: $\exp\{2\pi i\,[K/\Theta]t\}$ (or, the cosine : $\cos 2\pi\,[K/\Theta]t$), with K integer $\gtrless 0$, is equal to 1 for $t = t_n$ $(\forall n)$. Hence, only relatively to the effect on these samples, two exponential whose frequencies differ by $[K/\Theta]$ are absolutely indistinguishible. It is then possible, if one is only interested in these samples values $X(t_n)$ to fold back the $X(t)$ spectrum on any arbitrary frequency band of $[1/\Theta]$ extension and, in one more particular way, on the band $(-\Omega, +\Omega)$, with $\Omega = [1/2\Theta]$. If the spectrum of $X(t)$ itself is limited to this last band, this aliasing effect does not exist and the knowledge of the signal is equivalent to the knowledge of its samples $X(n/2\Omega)$, from $t_n = -\infty$ to $t_n = +\infty$ (2Ω samples per second): 58

$$X(t) = \sum_{n=-\infty}^{n=+\infty} X\left(\frac{n}{2\Omega}\right) \frac{\sin 2\pi\Omega\,[t - \frac{n}{2\Omega}]}{2\pi\Omega\,[t - \frac{n}{2\Omega}]} \qquad (1\text{-}1)$$

Let us assume that, according to the dynamics of the channel, the variation range of X(t) be $\{-(A/2), +(A/2)\}$ (Fig. 1)

From the existence of the noise, there results, for each sample, one limit to the precision which creates one quantization (Fig. 1) in such a way that the number of distinguishible values is equal to:

$$\frac{A}{b} + 1 \tag{1-2}$$

where b is a measure of the noise imprecision.

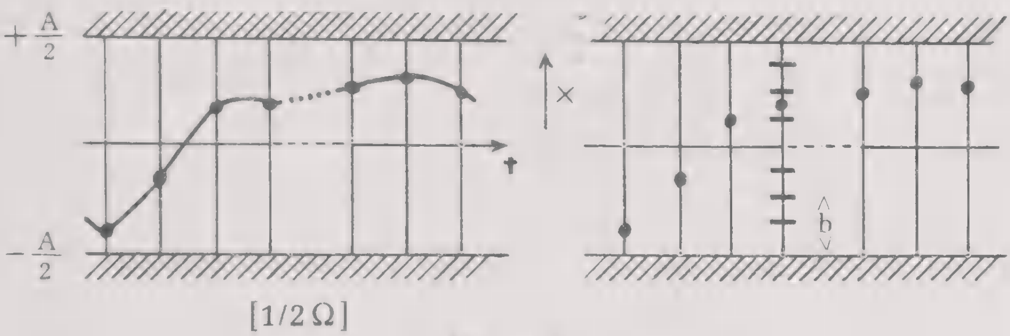


Figure 1

It is then easy to count the number of distinguishible signals the channel is capable of transmitting during time T according to its band, maximum amplitude and noise limitation. This number is

$$\mathscr{N}(T) = \left(\frac{A}{b} + 1\right)^{2\Omega T} \tag{1-3}$$

$\mathscr{N}$ (T) characterizes the maximum of information $\mathscr{I}$ (T) the channel can transmit during T seconds. It is natural to precisely define this quantity of information in such a way that it be proportional to T. For that, we put

$$\mathscr{I}(T) = \log \mathscr{N}(T) = 2\Omega T \log \left(1 + \frac{A}{b}\right) \tag{1-4}$$

If binary logarithms are used, $\mathscr{I}$ (T) is expressed in bits (quantity of information corresponding to the toss between two equiprobable possibilites). By putting $T = 1$ second, we obtain

the maximum information rate through the channel. It is the capacity of the channel:

$$C(\text{bit/second}) = 2\,\Omega \log_2 \left(1 + \frac{A}{b}\right) \qquad (1\text{-}5)$$

Generally, the expression of C is derived from the following hypothesis:

- gaussian stationary noise, with uniform spectrum on $(-\Omega, +\Omega)$ and with one given mean power B;
- stationary signal, with one given mean power S, independent of the noise.

With these hypotheses, (1-5) must be written

$$C = \Omega \log_2 [1 + (S/B)] \qquad (1\text{-}6)$$

C is a function of the pass band Ω and of the signal/noise ratio. (1-6) is similar to (1-5). In the following, we shall be referring to (1-6). We must point out that, in (1-6), the information rate corresponding to C is only obtained if the signal is gaussian, band limited to $(\Omega, +\Omega)$ and of uniform spectrum on this band. Moreover, to obtain this information maximal rate implies a delay in the transmission. This delay will be all larger that one desires to approach C more closely and with the smaller error probability.

I.2. BIDIMENSIONAL (OR TRIDIMENSIONAL) OBJECTS

The above considerations can be immediately extended to bidimensional or tridimensional objects.

In particular, the bidimensional case contains the case of the optical imaging.

What quantity of information can we transmit from one bidimensional object to its image?

We must now replace the time interval T by a bounded area in the plane of the object. 60

For time signals, the existence of the information rate derives from:

- the existence of a limited frequency band

— the introduction of quantification owing to the noise.

The same properties still hold: the frequency υ must be replaced by a bidimensional frequency $\vec{\upsilon}$ and the limitation in the $\vec{\upsilon}$ domain results from the different optical aberrations and, in any case, from the diffraction by the apertures of the optical device (Fig. 2). The quantification owing to the noise can be introduced as in the case of time signals.

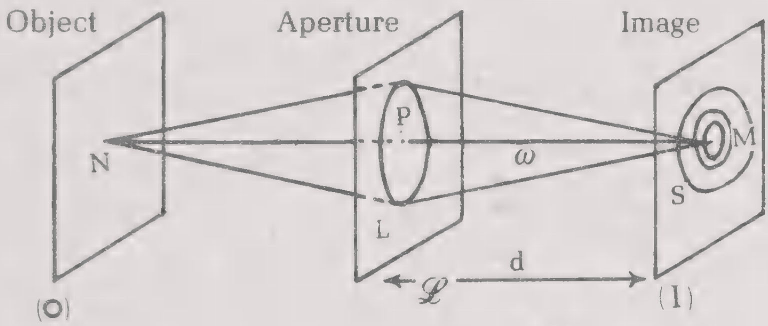


Figure 2

All the derivations for time signals are transposable. Let L be the surface of the diffraction aperture, ω the solid angle (in steradians) under which this aperture is seen from M, and S the considered surface in the image plane (that is to say the corresponding surface in the object plane if the enlargement is equal to 1). It can be established that the number of samples relative to this problem is $(2\omega S/\lambda^2)$.

For $S = 20 \times 20\ mm^2$ $\omega = 1/16$ steradian, $\lambda = 0.5\ \mu$, the number of samples is 2×10^8 .

Let us assume that we can only distinguish between black and white. Then, if the picture is so detailed as to separate all these samples, one gets 2×10^8 bits. One movie image contains about 10^5 bits. Then, in the considered surface of 4 cm^2, at least 2,000 images can be stored, that is to say more than one minute of film. In fact, according to the great redundancy of the successive images, it must be possible to store more images. This example illustrates the tremendous capacity of optical devices. This capacity is a consequence of the bidimensionality of the message, of the accuracy of the recording and of the playback, accuracy linked

iteslf to the great resolving power. As examples, the Videodisc and the digital optical disc Gigadisc (Thomson-C.S.F.), devices with laser recording, can, if few dm², store 10^{10} to 10^{11} bits. It is very superabundant to fully store the Bible [about 3000 pages of 3000 to 4000 types each (8 bits per type approximately) which corresponds roughly to only 10^8 bits.

II. TRANSMISSION OF INFORMATION OVER LONG DISTANCES WITH APPLICATIONS TO DEEP SPACE PROBES

II.1. PARTICULAR FEATURES

The missions into deep space require very reliable telecommunications. The probes must remain operational during very long distances (see Table 1 concerning Voyager I and Voyager II)

The reliability problems were designed for 4 years (2 years of flight to Jupiter and 4 years to Saturn). The encounter with Uranus needs 9 years and, with Neptune 12 years !

	Launch	Jupiter	Saturn	Uranus	Neptune
Voyager I	5 Sept 1977	5 March 1979	12 Nov 1980	goes into the interplanetary space	
Voyager II	End of April 1977	7 July 1979	25 Aug 1981	30 June 1986	22,23,24 Aug 1989
Distance approx. (km)		0.9×10^9	1.5×10^9	3×10^9	4×10^9

Table 1

II.2. CAPABILITY EVOLUTION

To illustrate this evolution, we only consider the scientific telemetry, that is to say the telemetry transmitting scientific data, values, images, collected by embarked scientific devices, cameras, ... neglecting the house-keeping, tracking and command telemetry which ensure correct operation and safety of the spacecraft.

Since the launching of the first deep space probes, the need for information transmission rates has greatly increased. The communication capabilities of improved equipment are increased transmitter power, antennas directivity, reduced receiver noise figures, etc,. A very significant contribution results from the improvements in signal processing methods and, particularly, in coding processing which enables operation with a lower signal/noise ratio. However, the transmission of coded signals requires a greater bandwidth.

The product of the binary rate multiplied by the square of the communication distance gives a good transmission quality factor for a deep space probe. Quality factor = 10 log (information rate x distance^2 . (2-1) Figure 3 shows the values of this quality factor four missions: Mariner IV (1964), Mariner VII (1969), Viking Orbiter (1975) and Voyager(+) (1977). The constant increase in the quality factor is seen in Figure 3.

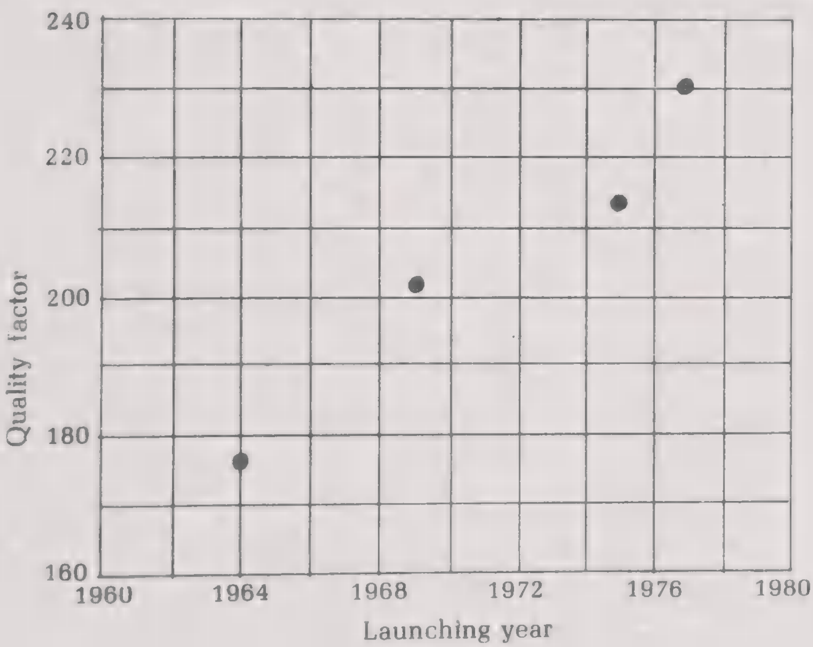


Figure 3

(+) *for Voyager, the quality is computed when passing near Jupiter*

C = 115 kbit/s $D \approx 8 \; 10^{8}$ *km.*

To illustrate the above, some data relating to the following launchings are presented here:

1. Mariner IV and Mariner VI which were put into orbit round Mars in July 1965 and in March 1969.

2. The probes Voyager (Jupiter, Saturn) (See Table 1).

MARINER IV AND MARINER VI and VII

For Mariner IV, the information was transmitted * at the rate of 8 bit/sec. For Mariner IV: 16,200 bit/sec (five minutes for one picture with Mariner VI and Mariner VII instead of 8 1/2 hour for Mariner IV.

It is interesting to analyse the factors which have lead to this spectacular improvement of a 33 db gain. These factors are numerous. The main part of this gain results from the systematic use of the ultimate possibilities of telecommunication techniques and from the exploitation of favourable cosmographic circumstances. The comparison is shown in Table 2.

	1964	1969	Gain (db)
Distance Mars-Earth (km)	216×10^6	97×10^6	6.84
Transmitter Power (W)	8.9	18.2	3.10
Ground Antenna (foot) aperture	85	210	8.5
Receiver noise temperature (°K)	65	25	4.10
Total			22.54

Table 2

However it was possible to gain the last dbs only by using very sophisticated signal processing techniques and, in particular, the Reed-Muller biorthogonal code. This gave a 2.2 db gain with a bit error probability of $5\ 10^{-3}$. Furthermore, some improve-

* Modulation system P.C.M./P.S.K./P.M. (Pulse code Modulation/Phase Shift Keying/Phase Modulation) combined with the use of pseudo-random synchronization code

Frequencies used by the satellite : 2,166 Mc/s at the reception and 2,298 Mc/s at the emission

ments in the coding allowed to avoid distinct synchronisation channel resulting in a supplementary 3.5 db gain.

VOYAGER

Some features concerning the probe→earth communication when passing near Jupiter, are given in Table 3.

Carrier	8.45 GHz
Information Rate	115.2 kbit/second
Distance	9.3×10^8 km
Receiver antenna gain	72 db
Transmitter power	21 W
Bandwidth	10^5 Hertz
Signal to noise ratio(+)	5.8 db (3.8)

Table 3

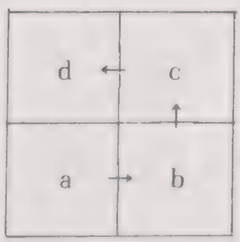
It is interesting to compute the rate corresponding to the theoretical maximum given by Shannon's formula [see equation (1-6)].

For (S/N) = 5.8 db (3,8), we have $C = 10^5 \log_2 4{,}8 = 2.25\ 10^6$ bit/sec.

For (S/N) = 2,3 db (1,7), we have $C = 10^5 \log_2 2{,}7 = 1.40\ 10^5$ bit/sec.

These values have the same order of magnitude as the value effectively obtained.

The **a** → **b** → **c** → **d** sequence of images corresponds to more and more extended processings (decrease of the low spatial frequencies, contrast adjustment by working on its histogram, . . .) image **a** being the raw picture, when arriving at the laboratory before final processing.



(+) *In this signal to noise ratio, is included a 3,5 db "safety margin" ; one accepts only 2,3 db signal to noise ratio threshold (with one bit error rate of 0.005). This because one needs to extract the maximum of scientific information from every spacecraft.*

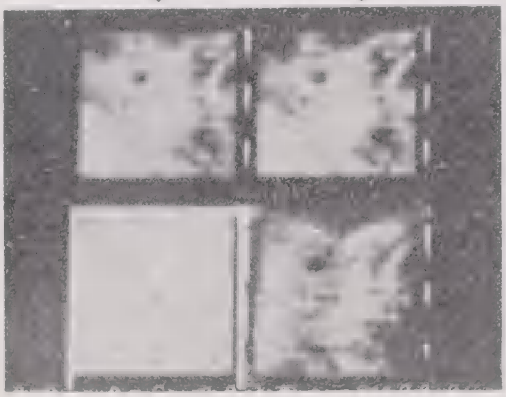


Plate 1

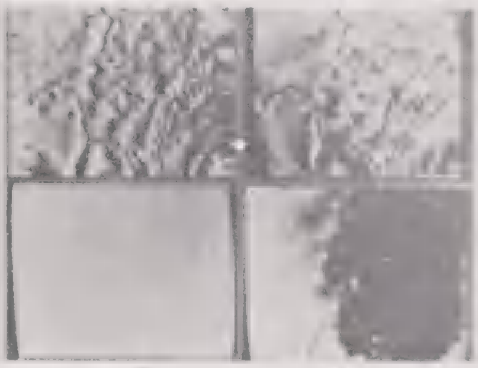


Plate 2

Plate 3

Plates 1, 2 and 3 show, for the imaging, the striking effects of signal processing on Mars landscape views (dunes and craters).

III. MULTIDIMENSIONAL IMAGING WITH APPLICATION TO MEDICAL IMAGING

III. 1. PRELIMINARY REMARKS

a) The introduction shows that information obtained considerably increases with the number of dimensions of the object. Then, we shall need to process more and more information for objects of 2,3......dimensions.

b) This is all the more true as the present tendency is increasingly to make indirect measurements.If one cannot directly measure the desired magnitude, with the desired accuracy, or if this magnitude is not directly accessible to the experiment, one measures "all one can", linked with it and containing some information correlated with it; then one extracts, possibly with very large computerization, the best estimation of the sought values. Fourier analysis goes this direction: instead of directly determining one optical spectrum by using spectral windows as in classical spectrometry, one measures the corresponding correlation function and the spectral density is then deduced by Fourier transform computation.

c) On the other hand, the tremendous improvement of the digitalized numerical techniques, offers possibilities of computer processsing which, in the last years, increased in a fascinating way. From 1955 on, in orders of magnitude, the various values characterizing the efficiency of this technique have been multiplied in accordance with Table 4.

Speeds	Multiplied by	10^4 to 10^6
Memory capacity	⟶	10^6 to 10^7
Reliability	⟶	10^8
Physical volume	⟶	10^{-4}
Price	⟶	10^{-4}
Energy consumption	⟶	10^{-4} to 10^{-7}

Table 4

III.2. TRIDIMENSIONAL OBJECT STUDIES TO MEDICAL PURPOSES

The problem is to obtain data concerning the morphological condition and the functions of some organs and to detect possible corresponding impairments. To do so, one seeks to know the

space distribution of some functions f(M) giving "indications" on the situation at a point M of the space. For example, f(M) will be the density at the point M, in such a way that the integral

$$\int_a^b f(M)\,dx \tag{3-1}$$

will define, by its exponential

$$\exp\left\{-K\int_a^b f(M)\,dx\right\} \tag{3-2}$$

the transmission factor for some X-rays propagating on (ab) (Fig. 4). This transmission factor itself is measurable "from the outside".

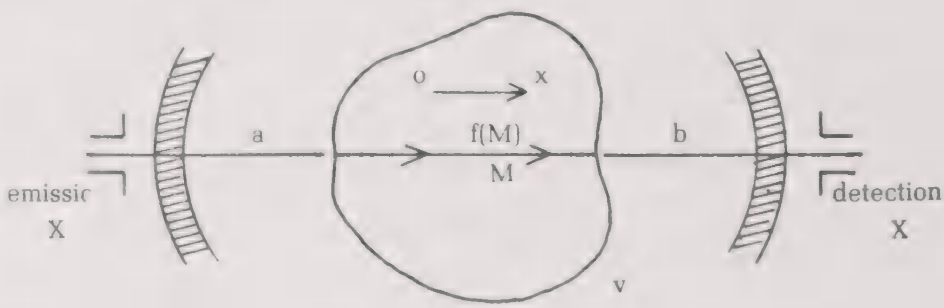


Figure 4

In other cases, f(M) can have different physical meanings. For instance, in nuclear medicine, f(M) can be some radiation emission density or particle emission density corresponding to radioactive isotopes selectively settled on particular organs. In the case of the Nuclear Magnetic Resonance (N.M.R.) f(M) will be, at every point M, either the proton density, or one of the two characteristic relaxation times: T_1 (spin-lattice) and T_2 (spin-spin). In any case one will measure external integrated effects and the magnitude f(M) itself is not directly accessible in situ. The considered magnitudes f(M) can only be magnitudes for which it is possible to define the addition. It was the case for absorptions (thanks to their logarithms), particle emission, N M R techniques, for the Free Induction Decay Signal. It should not be the case for temperatures.

It may be noted that the problems are complicated by the fact that the studied organ is only "seen" from outside through some tissues or bones in which one has no interest. For instance, let us consider Figure 4 suggesting the study of the brain by X-ray technique. The beam used must go through the skull-as hatched on the figure - so that the integral delivered by the experiment is the sum of the brain contribution and of the preponderant skull contribution. We have the case of a small signal mixed with a large parasite effect.

The object reconstruction, that is the derivation of the f(M) sought function from the measured integral values (3-1), can be performed:

- either according to the scanner X method. Then one uses a theorem proved by Radon a long time ago and very clearly understandable by using simple Fourier analysis. According to this theorem, it is possible to deduce f(M) at every point M from the knowledge of its orthogonal projections on all the planes containing one direction Δ arbitrarily fixed.(Fig.5). To state more precisely, the orthogonal projection of the tridimensional function $f(M) = f(x,y,z)$ on the plane xoy is the bidimensional function $\int f(x,y,z)\,dz$.

- or, in some cases -and this is particularly possible in N M R - by organizing measurements and processings in such a way as to have direct access to the Fourier transform of f(M).

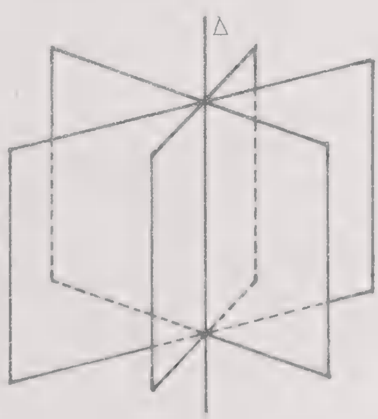


Figure 5

Plates 4 to 6 give some ideas on the present situation in medical imaging. These pictures reproduce images obtained by the Compagnie Gēnērale de Radiologie (Thomson - C.S.F., France).

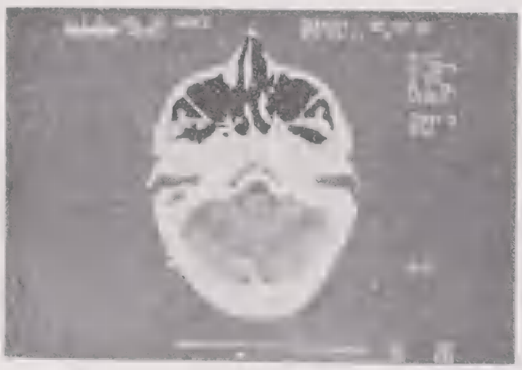
(without local normalization)

Plate 4

(with local normalization)

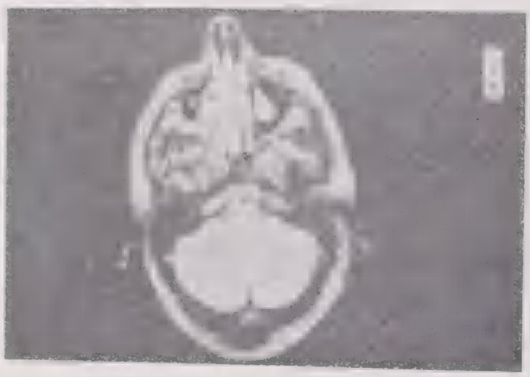
Plate 4a

Plates 4 and 4a:
Effect of local normalization in numerical X-ray imaging.



(Scanner X)

Plate 5



(N M R)

Plate 5a

Plates 5 and 5a :
Skulls : Scanner X and N.M.R.

Plate 6 : Brain (N M R)

The scanner X shows the hard parts of the body (bones) in which the density of matter is high. The NMR pictures show the soft parts with a high proton density. In Plate 5 (Scanner X), the white band which surrounds the skull exhibits the heavy bone whereas in Plate 5 a (NMR), the smaller white band results from the effect of the skin (rich in protons).

CONCLUSION

All we have seen so far shows how vast is the field of application of ideas, of reasoning modes, and of the techniques of information theory and signal processing, especially when they are supported by possibilities of computer science. There is no doubt that these ideas generate links and unity factors between various scientific domains, and constitute an invaluable tool for the advancement of what can be called Systems Theory, which has by no means reached its zenith yet.

However, as a physicist, I cannot but recollect that sytems are also made of components the deeper knowledge of which requires finer and finer studies of the properties of matter. Besides, such studies are absolutely necessary for any significant improvement in the field of signal processing. Lastly, I would urge that it is important for all of us to find a reasonable balance, in the development of academic syllabuses and research programmes between these two aspects of science and technology.

IMPULSE ACTIVITY NOT THE SOLE NEURAL DETERMINANT OF SKELETAL MUSCLE FIBRE TYPE

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Adult mammalian twitch muscle fibers are readily distinguishable into different types with distinct physiological, biochemical and structural characteristics. An outstanding fact that has emerged from the studies of muscle fiber types during the past two decades is that it is not rigidly fixed but can show plastic transformation from one type to another with cross-reinnervation i.e. with exchange of the nerve supplies between the fast and slow muscles [1,2]. It has also been established that the muscle fibers supplied by the same motoneuron are normally all of the same type [3,5]. These facts demonstrate that the type characteristics of muscle fibers are somehow determined by their motor innervation. But how does the motor nerve determine the muscle fiber type? Because, on the one hand, the transformation of fast-twitch muscle fibers brought about by cross-reinnervation with a slow nerve can be so well imitated by the effect of chronic low frequency stimulation [6,8] and on the other hand, attempts to show the transformation of muscle fiber type with cross-reinnervation after presumed abolition of impulse activity in the cross-reinnervation nerves through the isolation of the relevant spinal cord segment have so far led to either negative or uncertain results [1,9] it has come to be generally believed that the motoneuron determines the type characteristics of the muscle fibers it innervates through its impulse activity pattern which induces a

corresponding pattern of muscular activity. But is impulse activity the sole neural determinant of muscle fiber type? In recent years my collaborators and I have addressed ourselves to this question and performed experiments specially designed to shed light on it. I shall describe the rather tortuous path which our experimental effort followed, eventually arriving at a simple crucial experiment giving to the question under consideration the answer which I have used as the title of this paper.

Adult mammalian twitch muscle fibers are normally singly innervated, that is, each fiber possesses only a single endplate, and a muscle with its own nerve intact normally does not accept additional innervation from a foreign nerve. But when its own nerve is crushed or blocked in some way to temporarily denervate or inactivate the muscle fibers, then during this temporary period of denervation or inactivity, a foreign nerve can form new additional endplates on the muscle fibers. Later, when its own nerve regenerates to reinnervate the muscle again, or when the block is removed, we obtain muscle fibers doubly innervated by two different nerves. Making use of this fact, we conceived the following type of experiment,[10-12] Starting with a slow muscle like soleus (SOL) we could give it additional innervation from a nerve that originally innervated a fast muscle like the rate extensor digitorum longus (EDL). Conversely, starting with a fast muscle like EDL, we would give it additional innervation from a nerve that originally innervated a slow muscle like SOL. This was done in a two-stage operation as shown in Fig.1. In such doubly innervated muscle, usually only a small proportion of the fibers is successfully double innervated. These have to be selected out for study. This was done by first treating the muscle with ChE staining in order to make the endplates visible. Then the muscle fibers were dissected one by one. Only those fibers showing two endplates wide apart, usually 3-C mm apart, were used.

Now let us consider the sort of questions we may ask about such doubly innervated muscle fibers, as regards fiber type (fig.2). When a soleus muscle fiber received additional innervation from the EDL nerve, what type of fiber would it become? Would it remain a slow fiber, or would it be transformed into a fast fiber? Or would it become something intermediate between slow and fast? Or would it even become a sort of mosaic, the part innervated by the original nerve remaining slow, while

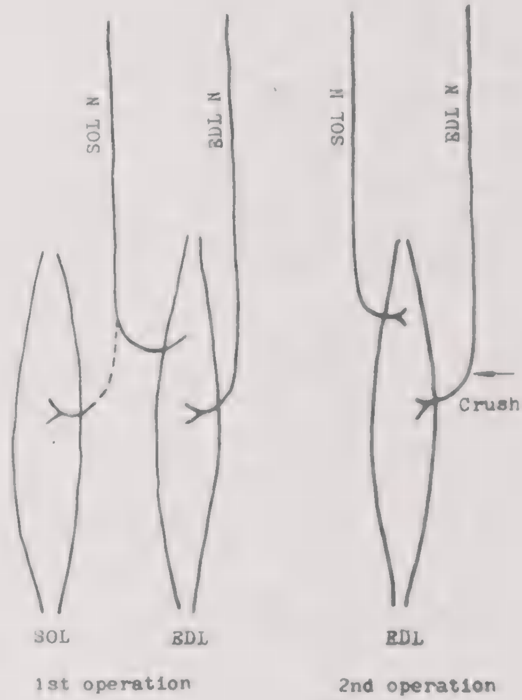

Fig. 1. Two-stage operation to produce doubly innervated muscle (EDL) fibers. In the 1st operation, the SOL nerve is cut near its muscle, and its proximal end implanted on to the surface of the EDL muscle near the proximal tendon, the implant being kept in place by plasma clot. The second operation is simply to crush the EDL nerve near the muscle.

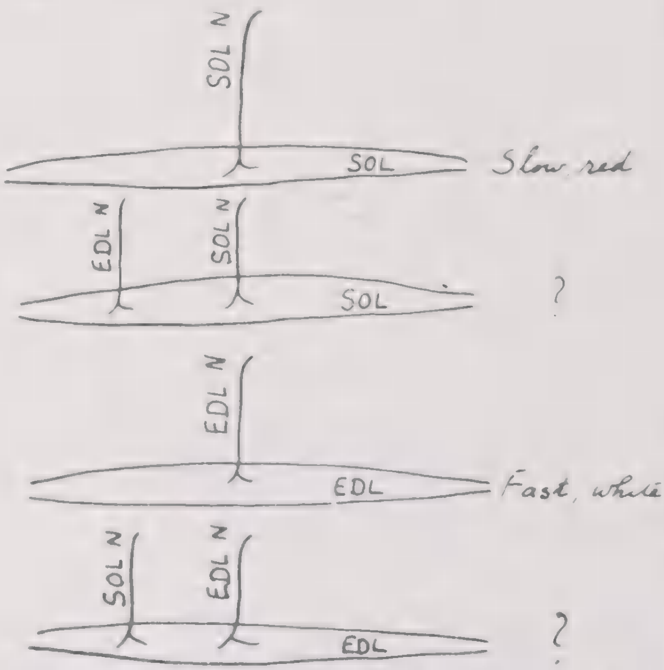

Fig. 2. Changes that take place in type in doubly innervated SOL or EDL muscle fibers.

the part now innervated by the foreign nerve becoming fast? The same set of questions can be asked of the EDL muscle fiber which has received additional innervation from the SOL nerve. As the discriminating characteristic of muscle fiber type, we first used the myofibrillar ATPase histochemical reaction. It is well known that with alkaline perincubation, the fast muscle fiber stains deeply while the slow fiber does not stain at all. What then is the ATPase histochemical type of the doubly innervated muscle fibers? Let us first see the doubly innervated SOL fibers (Fig.3).

It is seen that the histochemical type of the doubly innervated SOL fiber remains the same as the normal SOL fiber. Furthermore, the histochemical reaction appears to be uniform throughout the whole fiber. The region around the original endplate and that around the foreign endplate are indistinguishable. Now let us see the doubly innervated EDL fiber (Fig.4) examined 200

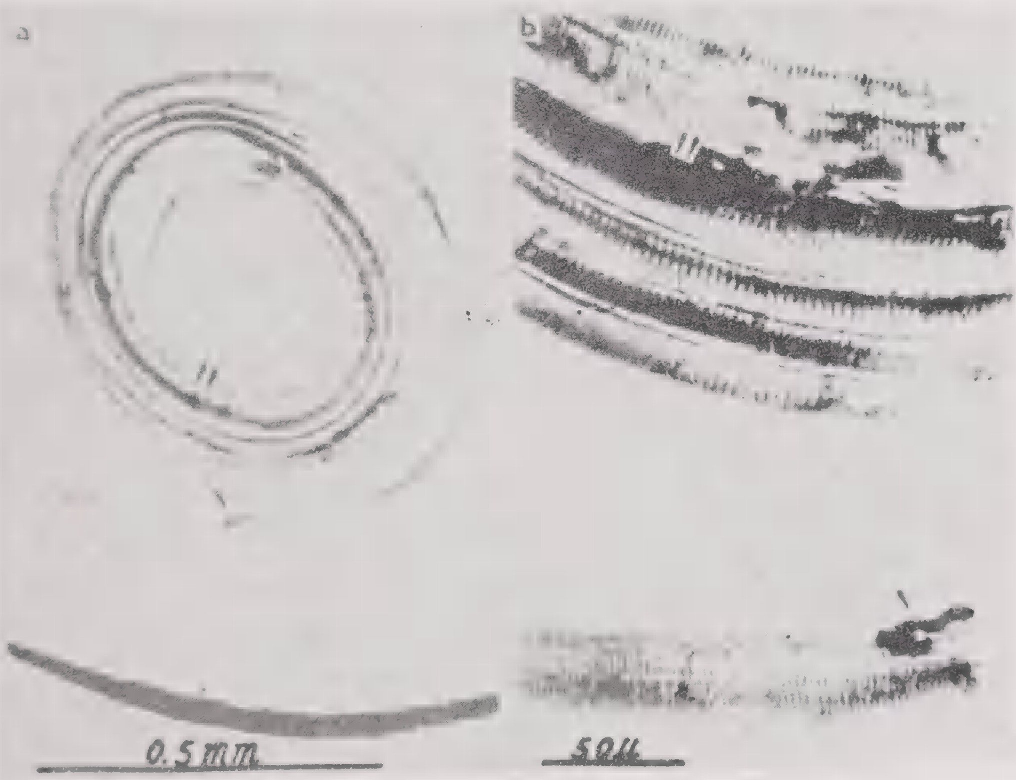

Fig. 3. Doubly innervated SOL fiber with type I histochemical reaction throughout, examined 90 days after crushing its own nerve, combined myofibrillar ATPase (pre-incubation at pH 10.4) and AChE method. b is enlargement of the parts of a containing the endplates (single arrow, original; double arrows, foreign). In a, is also shown a segment of deeply stained type II fiber for comparison.

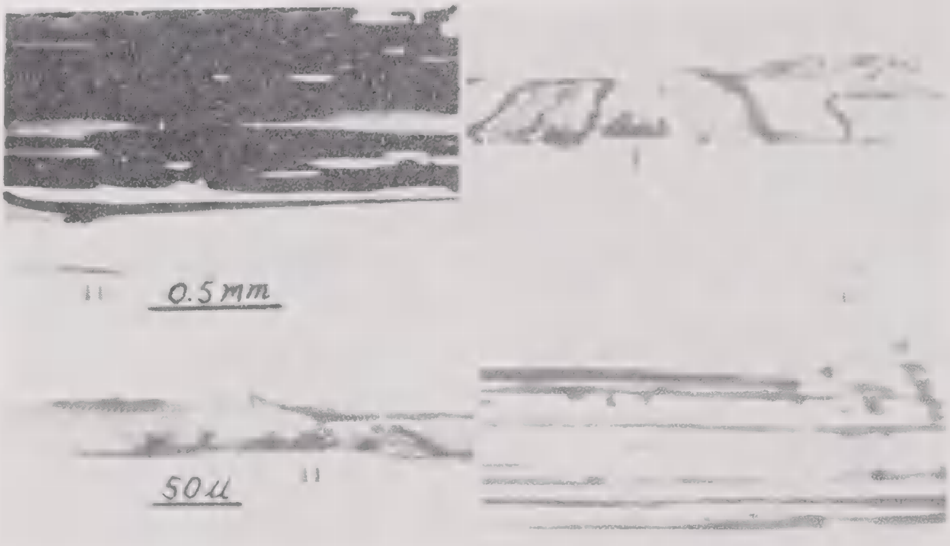

Fig. 4. Doubly innervated EDL. In the middle, a separated fiber with two endplates (single arrow, original; double arrows, foreign), exhibiting type I histochemical reaction throughout. Below it on the right is a part of the muscle receiving foreign nerve supply and containing many transformed fibers, hence staining like SOL; above left is an opposite part of the same muscle receiving no foreign nerve supply and containing no transformed fibers, hence staining like normal EDL. Insets at bottom left and top right are enlargement of the segments of the fiber in the middle containing the endplates.

days after crushing its own nerve, combined myosin ATPase (Preinculation at pH10.4 and ACHE method). The result forms a sharp contrast with the SOL fiber we have just seen. The EDL fiber after double innervation undergoes a complete transformation of histochemical type, that is, it becomes like the SOL fiber. Again it is important to note that the histochemical characteristic throughout the transformed fiber is uniform, the two endplate regions being again indistinguishable.

The above striking difference in the behaviour of the ATPase histochemical characteristic between SOL and EDL muscle fibers in response to double innervation, or rather, to additional innervation by a foreign nerve of different type, was an intriguing result. But it was by no means an isolated result. A parallel result was obtained with a very different discriminating characteristic of muscle fiber type, namely the Z-band width which is typically narrow for the fast EDL fiber and typically wide for the slow SOL fiber (Fig. 5.). After double innervation, the Z-band of the SOL fiber remains wide as in normal SOL fiber and the widths of the Z-band in the two endplate regions are the same (Fig. 6). But after double innervation the Z-band of the EDL fiber becomes completely transformed from the narrow to the wide type. Again the two

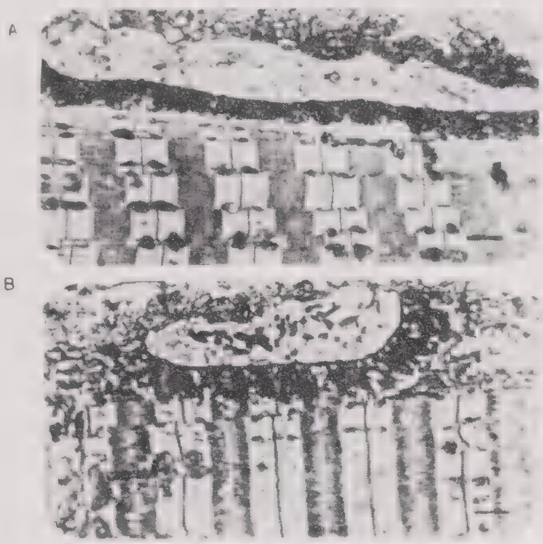

Fig. 5. Normal EDL (A) and SOL (B), showing their difference in Z-band width, M-line sharpness, mitochondria abundance and junctional folds density. Scale bar, one micron.

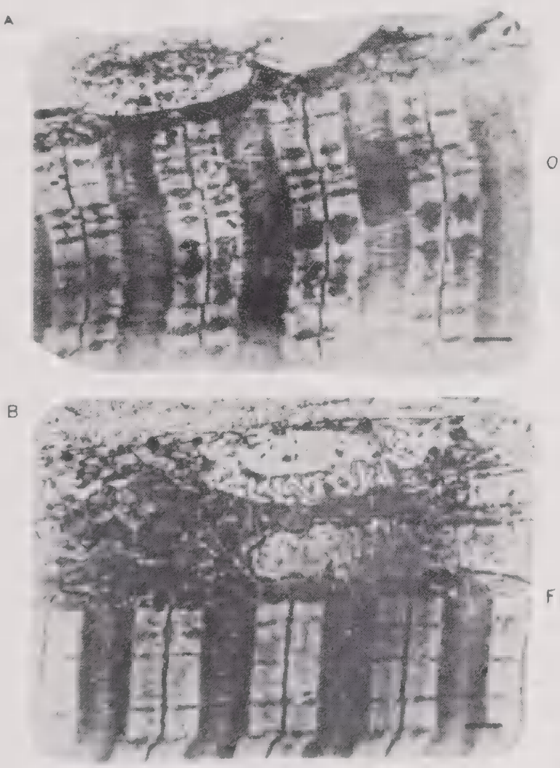

Fig. 6. Doubly innervated SOL fiber, 110 days after crushing its own nerve, showing Z-band width and subsarcolemmal mitochondria accumulation same as characteristic of normal SOL fiber in both endplate regions : A, under original endplate; B, under foreign endplate formed by implanted EDL nerve.

endplate regions of the transformed fiber have both wide Z-band essentially the same (Fig. 7). The above results are very interesting in more than one way. Here we shall refer back especially to one of the questions we have asked about doubly innervated muscle fibers regarding possible change in fiber type, namely would such muscle fibers become a kind of mosaic, that is, the part innervated by the original nerve retaining the original type characteristic, while the part innervated by the foreign nerve acquiring a different characteristic? This question is of special relevance to the problem we are investigating. If the motoneuron determines muscle fiber type solely through nerve impulse activity eliciting corresponding muscular activity, then, since muscular-contraction is propagated in twitch muscle fibers, whatever change is due to muscular activity is likely to take place uniformly throughout the whole muscle fiber. On the contrary, if the motoneuron also acts on the muscle fiber in some way other than through muscular activity, say, by the release of some neu-

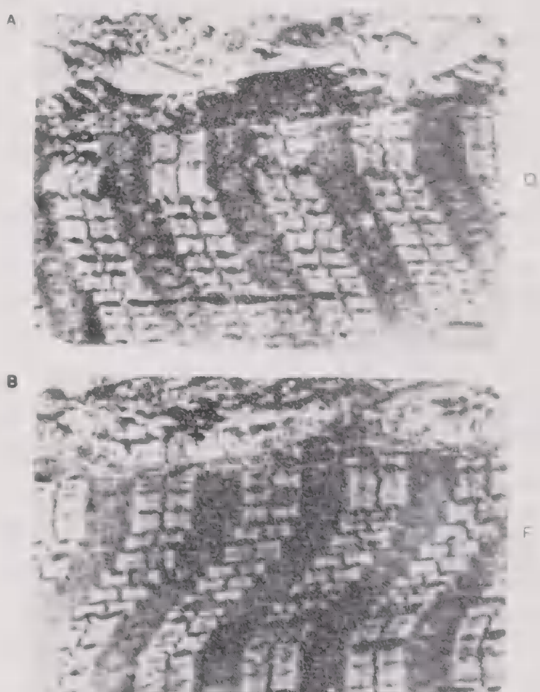

Fig. 7. Doubly innervated EDL fiber, 96 days after crushing its own nerve, showing complete transformation into SOL type with equal Z-band width of 80 nm and similar mitochondria density in the two endplate regions: A, under original endplate; B, under foreign endplate formed by implanted SOL nerve.

rotrophic factor, then in a doubly innervated muscle fiber, the two nerves, if they release two different neurotrophic substances might induce different local changes in the muscle fiber. Nevertheless the fact that doubly innervated muscle fibers show no local differences in the neighbourhood of the two endplates, as it stood, provided no support for the presence of neurotrophic factor in the neural determination of muscle fiber type. But in considering this result, a particular circumstance of the experiments on doubly innervated muscle fibers described above must be taken into account. Those experiments were all of long duration, lasting several months to over a year. We considered that the transforming influence due to some neurotrophic factor liberated by the foreign nerve, if such there were, would presumably start at the foreign endplate and then in some way spread to the rest of the muscle fiber. After a long period of cross-innervation, the change brought about by the transforming influence would get equalized throughout the whole fiber. But at a sufficiently early stage of the transformation, before the resulting change has enough time to become uniform along the fiber, a difference in the fiber characteristic, e.g. the Z-band width in the foreign endplate region and elsewhere might be found. This kind of consideration led us to study the early time course of the change in the Z-band width in the doubly innervated EDL muscle fibers, and we had a surprise. We found that within two weeks after the foreign SOL nerve began to form endplate in the EDL fiber, its Z-band width had already undergone a practically complete transformation (Fig. 8). This unexpected discovery indicated that in order to study the early course of the Z-band width change, observation needs to be made even earlier than 2 weeks after the second operation. This matter is being followed up. But the unexpected discovery just mentioned immediately enabled us to adopt a different experimental approach towards the problem on hand. In looking for the possible existence of some activity-independent neurotrophic factor in the neural determination of muscle fiber type, the crucial test one can readily think of is: Perform the cross-innervation with the under Chronical TTX and see if under such condition which excludes impulse activity, the cross-innervating nerve could still exert a transforming effect on the muscle fiber. This TTX experiment was not done earlier simply because it was thought impossible to maintain the TTX block long enough for studying cross-innervation effects. Now with the knowledge that cross-innervation of the EDL muscle fiber with the SOL

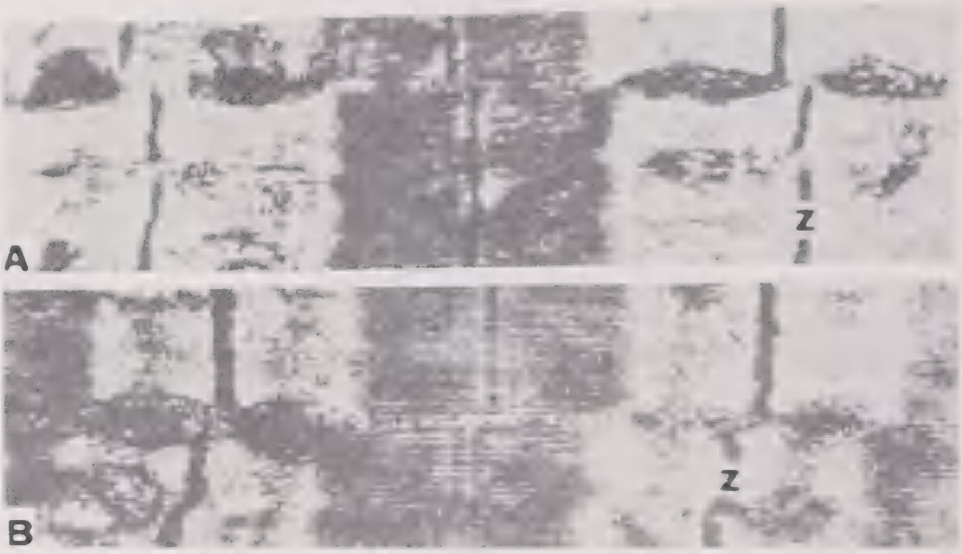

Fig. 8. A normal EDL fiber; B, EDL muscle fiber cross innervated by SOL nerve for 15 days, showing practically complete transformation of Z-band from the narrow to the wide type.

nerve could produce a practically complete transformation of Z-band width within as short a time as two weeks, the way to doing the TTX experiment was cleared and we immediately switched over to do it, as indicated in Fig.9 and obtained the exciting result as shown in Figs. 10 and 11 [13]. It is seen here that blocking its own nerve with TTX for 15 days does not change the Z-band width of the EDL muscle fibers. But cross-innervation of the EDL muscle fibers with TTX-blocked SOL nerve for 15 days caused a definite, though usually incomplete, transformation of their Z-band. A still more interesting result was obtained when the TTX-block was maintained during the establishment of double innervation of the EDL muscle fibers. It is seen in Figs. 10 and 11 that additional cross-innervation of the EDL muscle fibers with TTX-blocked SOL nerve caused a similar degree of transformation of their Z-band width even when their original nerve supply was intact though also blocked by TTX. The TTX experiment thus provides 80
a straightforward demonstration of the presence of some activity – independent factor in the transformation of Z-band width of the EDL muscle fibers by the SOL nerve and allows us to conclude that, at least with respect to some characteristic, impulse activity is not the sole neural determinant of skeletal muscle fiber type.

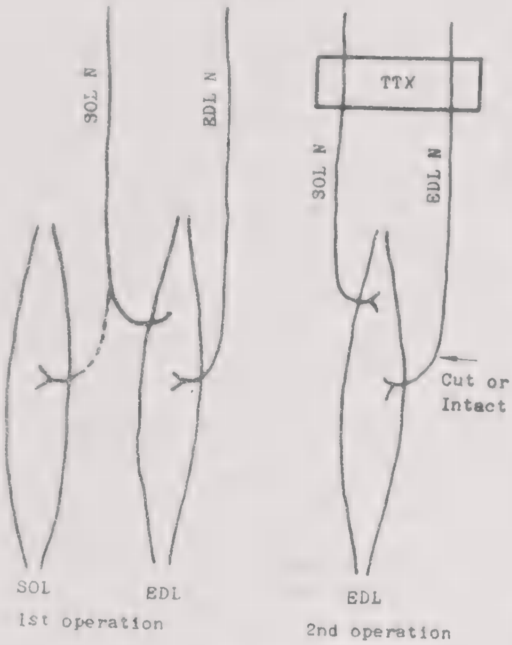

Fig. 9. Two-stage operations as in Fig. 1 except (a) beginning from the time of the second operation, the nerves were placed under chronical TTX block, and (b) in the 2nd operation the EDL nerve was either cut for simple cross innervation or left intact for double innervation.

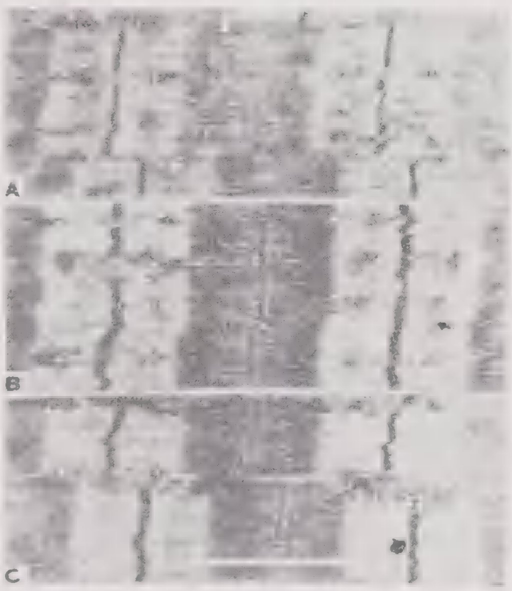

Fig. 10. Induction of Z-band width transformation in EDL muscle fibers by cross innervation with TTX blo ked SOL nerve. A. EDL muscle fiber with its own nerve blocked by TTX for 15 days; B. EDL muscle fiber with its own nerve sectioned and cross-innervated by TTX-blocked SOL nerve for 15 days. C. EDL muscle fiber with its own nerve intact and additionally cross-innervated by SOL nerve for 15 days, both nerves under TTX block. Scale bar, 2 microns.

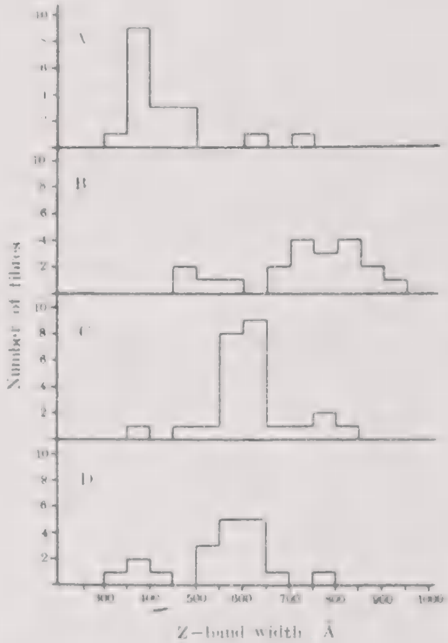

Fig. 11. Partial Z-band width transformation in EDL muscle fibers induced by crossinnervation with TTX-blocked SOL nerve. A. EDL fibers with their own nerve blocked by TTX for 15 days. B. EDL fibers cross-innervated by normal unblocked SOL nerve for 15 days; C. EDL fiber cross-innervated by TTX-blocked SOL nerve for 15 to 25 days; D. EDL fibers with their own nerve intact and additionally innervated by SOL nerve for 15 to 25 days under TTX block.

The problem of the mode of the neural determination of various type characteristics of the skeletal muscle fiber has been much studied for more than two decades. Although much has been learned, the problem remains open. Our new observation that TTX-blocked SOL nerve can still exert a transforming influence on the Z-band width of the EDL fibers, serves to stress this point. The demonstration of the presence of some neurotrophic factor which could act independently of impulse activity in the neural determination of skeletal muscle fiber type, does not lessen the importance of impulse activity in this determination. It only raises more problems. Given the fact that both neurotrophic agent and impulse activity play a role in the determination of muscle fiber type, there arises the question of the relative importance of the two factors, which may have to be assessed separately for each of the type characteristics of the muscle fiber. And though each of the two factors can be made to act independently under experimental conditions, one would expect some kind of interaction between them in normal muscle development and

function. The elucidation of this interaction now becomes a real experimental challenge.

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UNIVERSITY-INDUSTRY RESEARCH INTERACTION IN JAPAN

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Recently Japanese industry has made remarkable progress and has proved its ability to adapt to the changing demands and to avail itself of the opportunity in the world market. There is an increasing interest in many countries to know how Japan has achieved such a rapid progress in science and technology. Quite a few survey missions from other countries have visited Japan to learn the secrets of Japanese society which makes such rapid progress possible. Some of these people have an assumption that university-industry cooperation in Japan should have been successful and this is one of the important factors of the rapid and remarkable progress in Japan. Unfortunately, however, I cannot say we have very good cooperation between university and industry until today.

Before discussing university-industry research interaction in Japan, a brief explanation concerning general research activity in Japan will be appropriate.

The statistical data in my paper are taken from several 84
sources, and are therefore not always consistent.

RESEARCH AND DEVELOPMENT ACTIVITIES IN JAPAN

Figure 1 shows the total amount of research and development (R&D) expenditure in Japan in Fiscal Year 1981. R&D ex-

Fig. 1 Expenditure on R & D Research Sectors in Fiscal Year 1981

Source: Sorifu Tokei Kyoku Kagaku Gijutsu Kenkyu Chosa Hokoku. Report on the Survey of Research and Development, Showa 57 Nen (1982).

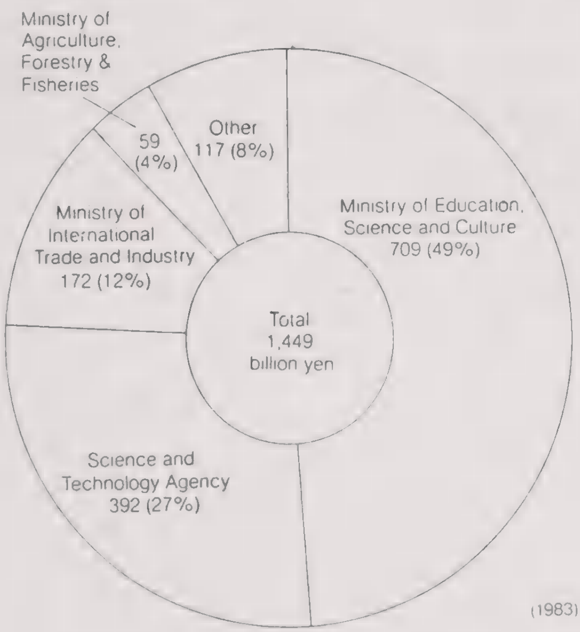

Fig. 2 Government Budget for Science and Technology by Ministries in Fiscal Year 1983.

Source: "Showa 58 Nendo Kagakugijutsu Kankei Yosan (Budget for Scientific Technological Research for FY1983-84). Gakujutsu Geppo (Japanese Scientific Monthly) Vol. 36, No. 2 (May, 1983; Tokyo, Japan Society for the Promotion of Science) pp. 6-29.

penditure in industry and in the universities is about 61% and 24% of the total R&D expenditure respectively.

The government budget for R&D in science and technology (excluding humanities and social sciences) in Fiscal Year 1983 was yen 1,449 billion, and about half of this went to the Ministry of Education, Science and Culture as shown in Fig. 2.

The Japan Techno-Economics Society (JATES) completed a very interesting investigation concerning university-industry research interaction in Japan. The results were reported to the Research Development Corporation of Japan (JRDC) and published in Japanese.

One of the results of the investigation is shown in Fig. 3, in which the flow of R&D funding from the government and from private sources to various sectors is presented.

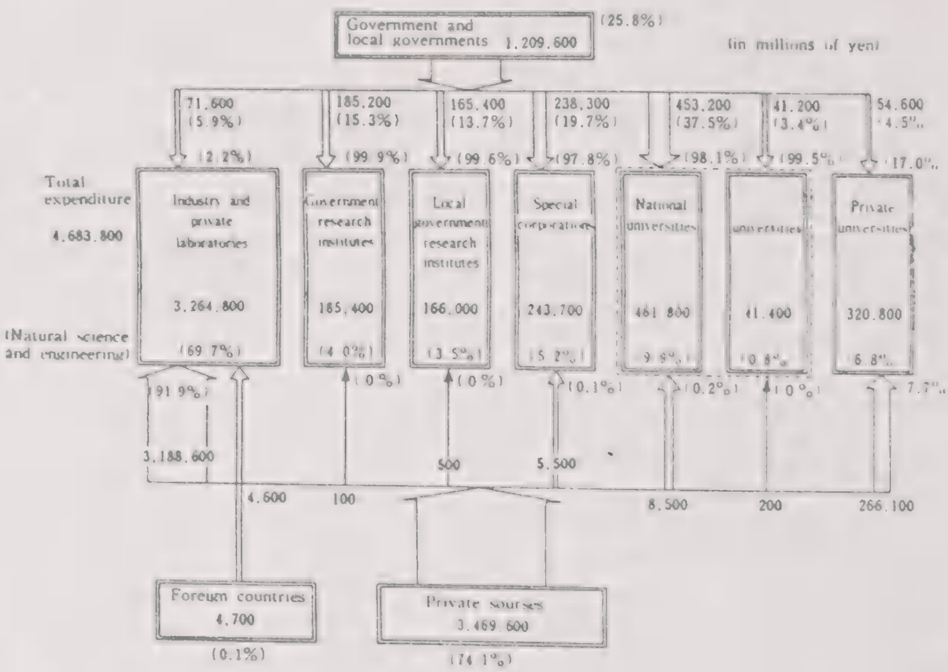

Fig. 3 R & D Funding in Japan for Fiscal Year 1980.

Source: Report by Research Development Corporation of Japan (JRDC), prepared by Japan Techno-Economics Society (JATES).

As of April 1982, the total number of research workers in Japan was 392,500 compared to 118,500 in April 1960. Fig. 4 shows the increase of qualified researchers by type of employer (universities, national and public research institutes and private companies). In 1960, research workers employed by private companies numbered 42,900 and their ratio to the total number of researchers was 36.2%. In 1982 researchers in the private companies numbered 192,900, and the ratio to the total number of researchers was 49.1%. The number of researchers in universities grew from 59,800 in 1960 to 163,200 in 1982, but in terms of their share of the total number of researchers the ratio decreased from 50.5% in 1960 at 41.6% in 1982. The number of researchers in national and public research institutes grew from 15,800 in 1960 to 36,400 in 1982, but the ratio decreased from 13.3% in 1960 to 9.3% in 1982.

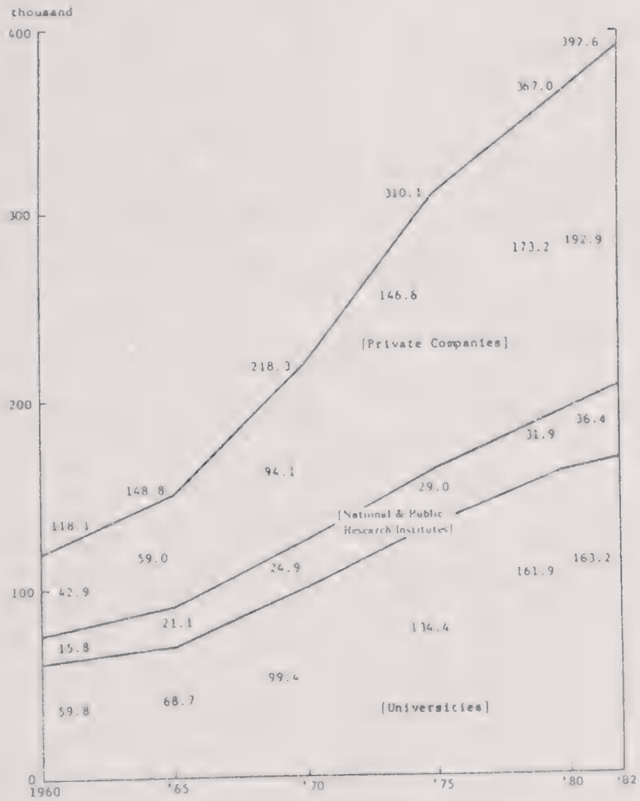

Fig. 4 Qualified Researchers by Employer

Source: Sorifu Tokei Kyoku (Statistics Bureau, Office of the Prime Minister) Kagaku Gijutsu Kenkyu Chosa Hokoku. Report on the Survey of Research and Development, Showa 35 Nen (1960); Showa 40 Nen (1965); Showa 45 Nen (1970); Showa 50 Nen (1975); Showa 55 Nen (1980); Showa 57 Nen (1982).

The Science Council of the Ministry of Education, Science and Culture conducted a study to estimate future demand of research workers in order to supply data for the discussion on training research workers. Estimations were made assuming various cases, and a typical result shows increase in researchers after 18 years in industry, universities and national and public research institutes to be 250,000, 16,000 and 700 respectively. This means the ratio of researchers in private companies, universities and national and public research institutes to the total number of researchers in Japan in the year 2,000 will be 67.2%, 27.2% and 5.6% respectively. As for R&D manpower resources in Japan, the number of researchers in industry is increasing much more rapidly than those in the other two sectors, and research and development in industry is expected to play a very important role.

RESEARCH ACTIVITIES IN THE UNIVERSITIES

The budget of the Ministry of Education, Science and Culture in respect of scientific research in Fiscal Year 1983 amounted to 861.6 billion yen. Among the major items were 1) research

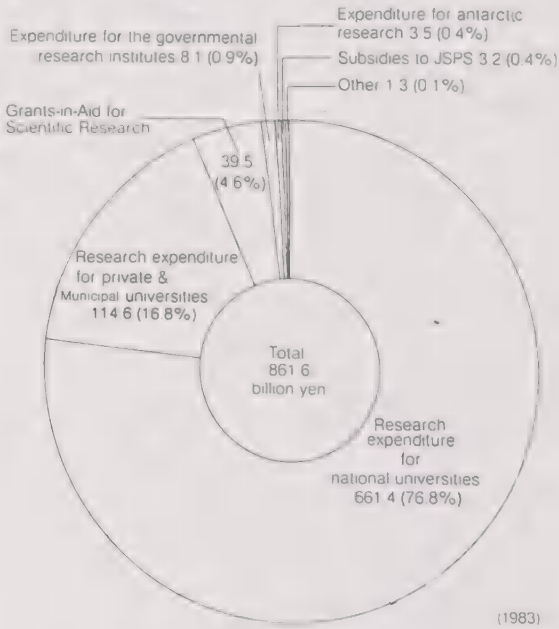

Fig. 5 Budget of MESC (Ministry of Education, Science and Culture) for the Promotion of Scientific Research in Fiscal Year 1983

Source: An Outline of the University-Based Research System in Japan (Monbusho).

expenditure for national universities (76.8%); 2) research expenditure for private and municipal universities (16.8%); 3) grants-in-aid for scientific research (4.6%); 4) expenditure for governmental research institutes (0.9%); 5) subsidies to Japan Society for the Promotion of Science (JSPS) (0.4%) etc. as shown in Fig. 5.

One of the characteristics in Japanese universities is that the faculty of engineering has occupied a central place within the higher education and research system since as far back as 1870, when the Japanese government introduced modern science and technology from advanced countries and launched a modern educational systems.

Today, 19% of all undergraduate students and 32% of all post-graduate students are in the field of engineering. In the national universities, the proportion of engineering students is 27% at the undergraduate level and 40% at the post-graduate level.

Research and development expenditure at engineering departments in Japanese universities in Fiscal Year 1980 is shown in Table 1.

Type of universities	Number of universities	R & D expenditure (in million yen)				Component ratio			Number of researchers
		Total	Basic research	Applied research	Development	Basic research	Applied research	Development	
National	155 (55.6%)	162.300 (60.4%)	84.800 (55.5%)	48.800 (62.8%)	28.700 (75.1%)	52.2	30.1	17.7	16.309 (57.7%)
Municipal	12 (4.3%)	10.600 (3.9%)	5.700 (3.7%)	4.300 (5.5%)	700 (1.8%)	53.3	40.3	6.4	1.417 (5.0%)
Private	112 (40.1%)	95.600 (35.6%)	62.200 (40.7%)	24.600 (31.7%)	8.700 (22.8%)	65.1	25.7	9.1	10.546 (37.3%)
Total	279 (100 %)	268.500 (100 %)	152.700 (100 %)	77.700 (100 %)	38.200 (100 %)	56.9	28.9	14.2	28.272 (100 %)

Table 1 R & D Activities at Engineering Departments of Universities and Colleges in Fiscal Year 1980

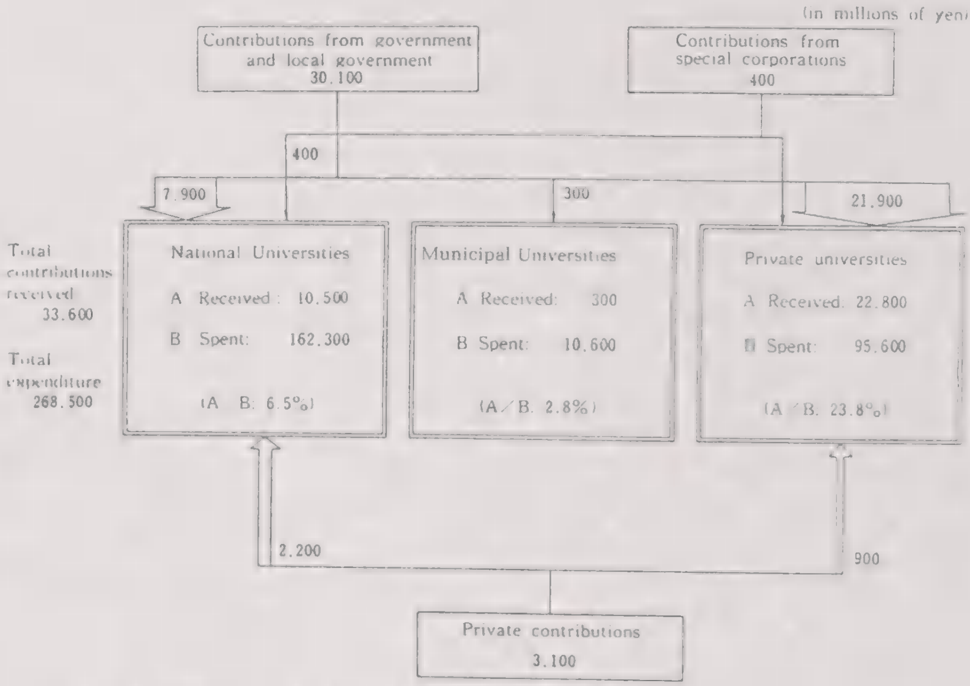

Fig. 6 R & D Contributions Received by Engineering Departments of Universities in Fiscal Year 1980

Source: Report by JRDC.

Research funding received by university engineering departments in Fiscal Year 1980 is shown in Fig. 6. This shows that very little funding is supplied from outside to the national and municipal universities in Japan.

RESEARCH AND DEVELOPMENT ACTIVITIES IN INDUSTRY

R & D activities in industry by capital size are shown in Tables 2 and 3. It is quite clear that large enterprises are very active in research and development, both in terms of research manpower and funding, while small and medium enterprises find it difficult to carry on basic research. Therefore goals and problems in university-industry cooperation may be different in the case of the large enterprises as compared with smaller companies.

UNIVERSITY-INDUSTRY RESEARCH INTERACTION

About a hundred years ago, when Japan started to introduce modern science and technology from western advanced countries, highly educated research workers were very scarce and most of them were working in the national universities and go-

Capital size	Number of companies	Number of researchers	R & D expenditure			
			Self-defrayment	Contributions to the outside	Contributions from the outside	Expenditure per head
~100MY	12.003 (76.9%)	22.343 (12.8%)	204.200 (7.4%)	13.000 (6.8%)	2.800 (2.3%)	9.26
100~1.000	2.638 (16.9%)	30.002 (17.2%)	325.400 (11.7%)	20.700 (10.9%)	22.000 (18.3%)	11.58
1.000~10.000	840 (5.4%)	45.661 (26.1%)	711.000 (25.7%)	31.500 (16.6%)	25.300 (21.1%)	16.13
10.000~	130 (0.8%)	76.790 (43.9%)	1.530.000 (55.2%)	125.000 (65.7%)	69.800 (58.2%)	20.83
Total	15.611 (100%)	17.479.600 (100%)	2.770.600 (100%)	190.200 (100%)	119.900 (100%)	16.54

Table 2 R & D Activities of Manufacturing Enterprises by Size of Capital in Fiscal Year 1980

Source: Report by JRDC.

Capital size	R & D expenditure by type of research				Component ratio		
	Total	Basic research	Applied research	Development	Basic research	Applied research	Development
~100MY	206,800 (7.2%)	3,800 (2.6%)	20,000 (3.6%)	183,000 (8.4%)	1.8	9.7	88.5
100~1.000	347,100 (12.0%)	14,000 (9.6%)	49,400 (8.9%)	283,700 (13.0%)	4.0	14.2	81.7
1000~10,000	734,700 (25.4%)	38,400 (26.3%)	151,800 (27.4%)	544,600 (24.9%)	5.2	20.7	74.1
10,000~	1,599,500 (55.4%)	89,900 (61.5%)	332,300 (60.0%)	1,177,200 (53.8%)	5.6	20.8	73.6
Total	2.888.200 (100%)	146,000 (100%)	553,600 (100%)	2,188,500 (100%)	5.1	19.2	75.8

Table 3 Type of R & D Activities of Manufacturing Enterprises by Size of Capital in Fiscal Year 1980

Source: Report by JRDC.

vernment research institutes rather than in industry. Moreover, university faculty members and government officials had better opportunities to study abroad than industry personnel. Therefore industry relied heavily on scientific knowledge from universities, and the university professors were really the leaders in their fields. They had close relations with related industries and were often asked to make basic designs and specifications for new products.

Recently, however, research and development activities in Japanese industry have been strengthened considerably. Although Japanese industry expects the universities to provide good engineers and scientists, it does not necessarily rely on universities for research activity itself. Because the primary responsibility of universities lies in education, they have difficulty concentrating manpower for a specific research project. Industry, on the other hand, is free to bring together many engineers and scientists in the same field to carry out promising research and development. In general, university-industry research cooperation in Japan has become very poor at present.

In order to clarify the present status of university-industry research interaction in Japan, the flow of research funds from industry to national universities is shown in Fig. 7 and Table 4.

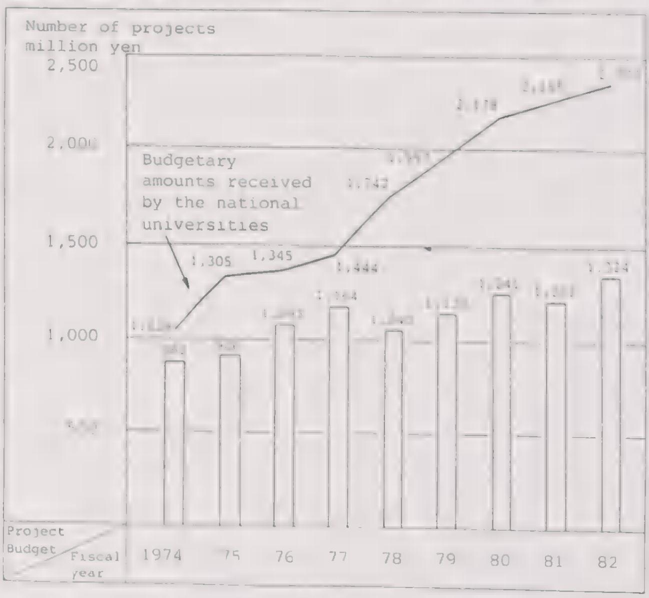

Fig. 7 Trends of Contract Research

Source: Ministry of Education, Scinece and Culture (MESC).

(million yen)

Fiscal Year \ Items	Total		Foreign		Domestic	
	Cases	Amount	Cases	Amount	Cases	Amount
1975	8,082	4,423	54	114	8,748	4,309
76	10,218	4,642	43	78	10,175	4,564
77	11,414	5,523	51	86	11,363	5,436
78	12,821	6,596	38	60	12,783	6,535
79	14,102	8,076	30	43	14,072	8,032
80	15,972	10,165	23	60	15,949	10,105
81	18,606	11,659	28	42	18,578	11,616
82	21,137	13,168	17	33	21,120	13,135

Table 4 Trend of Donations to the National Universities

Source: MESC.

There are two ways to supply research funds from outside to universities. One is contract research, and the other is research donations.

Fig. 7 shows the total cases and expenses of contract research, and Table 4 shows the amounts of donations from outside to universities. Although there is no exact data on number of cases and expenditure for research concerning donation, it can be estimated that about half may be spent for research and the other half for education. Research funding from outside was about 9 billion yen in 1982, while the total expenditure for university research was about 640 billion yen. This shows that research funding by contract research or donation from outside is only about 1.4% of the total expenditure for research. Moreover the amount of funding per case is very little. More than half of the contract research is conducted under funding of less than one million yen, and the average amount of research funding for contract research is from one to two million yen.

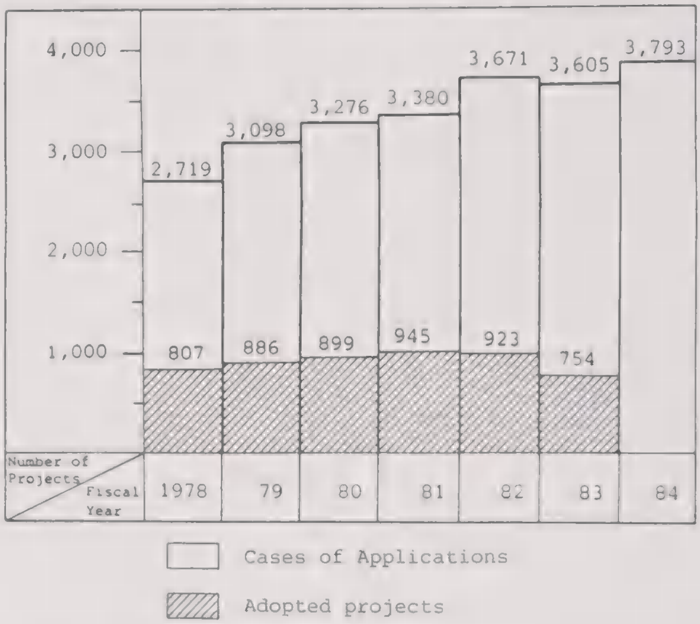

Fig. 8 Trend of Grants-in-Aid Program for Experimental Research

Source: MESC.

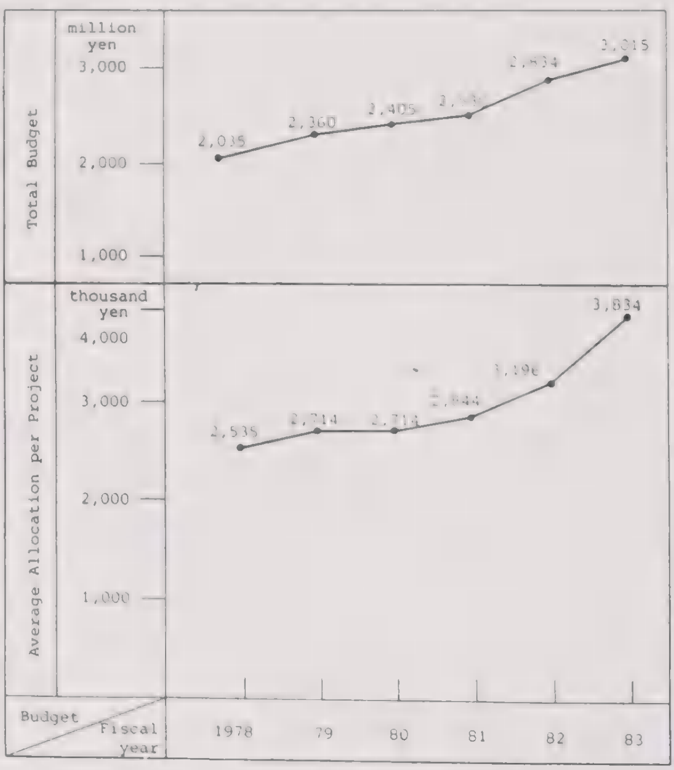

Fig. 9 Budgetary Trend of Grants-in-Aid Program for Experimental Research (Excluding personnel cost)

Under the Grants-in-Aid Program for Scientific Research, research grants are awarded directly to individual researchers or group of researchers. The budget for this program was yen 39.5 billion in Fiscal Year 1983 as shown in Fig. 5. One of the categories of the Grants-in-Aid Program is "Experimental Research," which aims to encourage applied research based on results obtained from basic research which can be carried out jointly by university researchers and researchers in industry. Trends in the Grants-in-Aid Program for Experimental Research are shown in Figs. 8 and 9.

As for exchange of scientists and engineers, there are various modes of exchange, including:

From industry to university

1) Lecturers from industry or governmental institutions.
2) Temporary researchers from industry or governmental institutions.

From university to industry

1) Professors engaged in R & D in industry.
2) Student practice in industry.

Table 5 shows the number of researchers temporarily received by universities from governmental and industrial institutions.

Number of Contracts Researchers			
Fiscal Year	National Government Employees	Private Company Employees, etc.	Total
1975	83	568	651
76	76	550	626
77	71	558	629
78	83	580	663
79	73	635	708
80	67	666	733
81	64	684	748
82	67	694	761

Table 5 Trend of Contract Researchers Received by the National Universities

Source: MESC.

Although many students receive practical training in industry, very few professors are engaged in research and development in industry.

There are many barriers to university-industry research cooperation in Japan. First, there is a lack of information in both universities and industry. University professors do not know the real need of research and development in industry, and industry engineers do not know what kinds of research is going on in universities. In order to overcome this difficulty, the Japan Society for the Promotion of Science (JSPS) has been providing a forum for promoting cooperation between the universities and industry by creating Industry-University Cooperative Research Committees on specific themes where researchers from both industry and the universities meet and discuss recent research results. Since 1933, 147 such committees have been organized, 34 of them are still active. The other committees have been dissolved after fulfilling their assignments. These committees have been established at the initiative of scientists both in industry and the universities, and have been supported by industry funding. Recently an attempt has been made to encourage the organization of new committees in certain specific fields in which exchange of information between universities and industry is likely to prove useful in the future. These new committees will be supported by government funding for three years, after which time industry funding will be sought, if the committee in question is thought to be useful.

Another barrier to university-industry cooperation is the potential conflicts which exist between universities and industry. In general, university research is planned for long range of objectives, while research in industry needs results by a definite deadline. The university researchers can initiate a research project just on the basis of scientific curiosity even if it is highly risky, but industry engineers usually choose their research projects based on the need for concrete results oriented towards current company problems, and are usually unwilling to run too high a risk. As the achievements of university professors are usually recognized by their publications, their research results tend to be open, but results of research in industry are often confidential. These kinds of conflicts between universities and industry impede smooth university-industry cooperation.

Moreover, Japanese universities, especially national universities, have strict regulations for their staff. University professors have been prohibited from engaging in part-time consulting activity to private companies. After World War II a strong anti-war feeling prevailed in the academic community and hindered cooperation with the industry which once supported the Japanese army and retain a possible cooperative link with Japanese defence.

The most serious distrust was created between universities and industry during the industrial technology catch-up period. Japanese industry made very energetic efforts to introduce advanced technology from the United States and Europe, thinking university research in Japan was too slow and too remote from industrial problems. Although there were some inventions and discoveries made by Japanese university researchers, they had not been highly regarded in the Japanese academic community. Their value was sometimes recognized by foreign scientists and then reimported back to Japan.

As I explained above, systematic cooperation between university and industry in Japan is very poor. However, significant collaboration between Japanese universities and industry has been made in indirect or informal ways. Quite a few university professors join as project leaders, advisors or investigators on government-sponsored projects or research committees in academic societies in which researchers in both universities and industry are conducting joint research. Industry scientists often ask university professors to give advice free of charge. They in turn provide generous support to university professors by making experimental instruments, devices and materials available free of charge or at a reduced price. Quite a number of top managers in Japanese industry have an engineering background; this means that professors whose former students are executives in industry can informally collaborate with such companies very easily.

This kind of fruitful cooperation, however, can only be enjoyed by well-known professors in large universities. In addition, the way of thinking among young people is changing very rapidly in Japan, and the informal or personal cooperation now existing between universities and industry might become difficult in future.

Considering the situation, many opinions and recommendations are being voiced from various corners in order to strengthen the linkage between universities and industry. The following are major recommendations being adopted to enhance university-industry cooperation.

(1) MINISTERIAL LIAISON COMMITTEE OF SCIENCE AND TECHNOLOGY

The Ministerial Liaison Committee of Science and Technology consisting of seven ministries (Education, Science and Culture; Science and Technology; International Trade and Industry; Agriculture, Forestry, and Fisheries; Finance; Economic Planning; Prime Minister's Office) was established in October 1980 and on 19th December 1980 after 6 meetings in two months, adopted recommendations concerning the fundamental aspects of science and technology policies. Among 7 items of the recommendations, Item 4 dealt with the cooperation between university and industry:

> Item 4
>
> Strengthening organic cooperation among academia, industry and the government
>
> It is necessary for academia, industry and the government to strengthen organic cooperation for the promotion of joint projects by concentration of their expertise, technologies and vitality under desirable allocation of roles. To meet this end, it is recommended, if necessary, to carry out research by smooth exchange of researchers and to reinforce exchange of information by strengthening liaison activities in research fields of common interest.

(2) THE AD-HOC COMMISSION FOR ADMINISTRATIVE REFORM

The ad-hoc Commission for Administrative Reform was established under the Prime Minister's Office in March 1981 in order to make a general review of the government administration and to examine and discuss fundamental measures of its reform within the perspective of the 1980's and thereafter.

The Commission submitted to the Prime Minister in July 1982, its basic report on administrative reform. The report contains, among others, the following recommendations concerning the relations among industry, academia and government, which are similar in their basic tone to the above proposal of Ministerial Conference of 1980, but more elaborate in their content:

i) It is necessary to establish a system that can promote scientific and technological research in a harmonious manner, through a clear division of burden to be shared by public and private sectors, and a clear division of roles to be played by the universities, national research institutes, etc. It is also necessary to promote research and development in a more efficient aand concentrated manner by strengthening the linkage among industry, academia and government and by utilizing the research and development capacity of the private sector.

ii) In promoting the country's future research and development, the capacity of the private sector should be utilized as far as possible, and the research and development activities of the government should be focussed on those related to its administrative affairs and others that cannot be left to the private sector. In this connection, universities should mainly conduct basic scientific research, while national research institutes should mainly conduct research and development that is based on administrative needs of the government or that cannot be expected of the private sector.

iii) Appropriate measures should be taken concerning the publication of the outcome of research conducted by national research institutes, universities, etc. so that researchers will be encouraged to publicize their research results and that peer evaluation in a large community of researchers will be made possible. With these measures, practical utilization of the fruits of research activities may be more widely realized.

iv) It is necessary to promote an organic linkage between researches in the universities and those in government and private industry, while special consideration is required as

regards the former in view of the necessity to ensure the freedom of scientific research.

(3) SCIENCE COUNCIL

In November 1980, in the meanwhile, the Minister of Education, Science and Culture asked the Science Council, its advisory organ, to prepare recommendations on the "Basic Policy and Measures for the Improvement of the Scientific Research System". The Council is to submit its final report to the Minister early in 1984. Among the major items for deliberation is that concerning "Response of Scientific Research to Social Demands" and in its interim report submitted in July 1983, the Council clarified its basic position on this issue as follows:

i) The fundamental mission of the university in its research aspect is to conduct advanced and creative research in any field chosen, with free and unrestricted minds and imagination, and to educate and train young researchers of promising abilities. In this way, the university, in the longer term, can meet various requests and expectations from the society.

ii) With this basic position in mind, the university should cooperate on its own initiative with other sectors of society for the exploration and solution of concrete problems or projects of the society, and stimulate its academic research.

The Council then proposed in its report the following measures:

iii) Measures to improve the mechanism of identifying social demands

a) to pay particular attention to the functions of the Science Council and various academic organizations.

b) to strengthen the activities of JSPS for the cooperation between the universities and industry including the establishment of a "Cooperative Liaison Committee on Research Activities" to advance the comprehensive and systematic cooperation between university and industry from a longterm standpoint.

c) to promote the exchange of researchers and information between the universities and other research institutions.

iv) To improve the systems of contract research, joint research etc.

a) to simplify the procedure for handling the contract research and to establish in each university an appropriate system of handling contract research and a central body for providing information service on contract research.

b) to further develop the newly established joint research system between researchers both from university and industry.

c) to improve the handling of patents resulting from contract research in such a way that the contracting firm is given preferential access to the use of the patent and that in the case of joint research the patent can be owned jointly by the research from the university and those from outside.

d) to promote the participation of researchers outside the university in the research activities under the Programme of Grants-in-Aid for Scientific Research.

e) to develop innovative research equipments in collaborating activity with industry, if necessary, and to consider appropriate means to enable researchers both from the university and outside to make use of such equipments.

f) to authorise the President or Dean of the university to permit their researchers to engage in advisory services for private companies on condition that those services are significant for and compatible with their academic research activities.

GEOMEDICINE

J LÅG

President of the Norwegian Academy of Science and Letters, Oslo

Among the souvenirs, congratulations and greetings presented to the Indian National Science Academy for "The Golden Jubilee " there is a book on geomedicine. The specific term may not be well known, but as an introduction we may cite some examples typical of the problems peculiar to the subject.

Some diseases in humans and animals appear in local geographical areas. Goitre is a typical example. At an early stage it was proved that intake of iodine prevented the illness. Certain forms of human dwarfism may be traced to zinc deficieny. Phosphorus deficiency can cause osteomalaci. Likewise, we have many cases of toxic effects that have resulted in diseases of endemic character.

DEFINITION

Knowledge of geomedical problems has existed for a long period of time. Hippocrates, it seems, was acquainted with such problems.

As far as we understand, the term geomedicine was intro- 102
duced into the literature over fifty years ago, though, different authors have used the term with different meanings. Geomedicine covers a series of heterogenous problems. Perhaps some will say the questions are too widespread to be covered under one subject. Another contradiction can be that many of the problems inc-

luded in geomedicine could be covered in previously established subjects. However, it has happened before that border-lines between different conceptions have been moved and new subjects have been introduced. For example we may here consider the great changes that have taken place in the biological range of subjects. Biology covers quite a larger area now than at the beginning of this century.

On the basis of existing knowledge I have suggested the following definition. Geomedicine is the science dealing with the influence of ordinary environmental factors on the geographical distribution of problems of human and animal health.[1,2] Pathological as well as nutritional problems of human and veterinary medical interest are included in this definition of geomedicine. On the other hand, plant pathology (cf. the definition of geophytomedicine) is not included in this terminology. Of course, we find relationships between plant diseases and medical problems. For example the deficiency of nutrients or toxification of plants may result in health disturbances further in the nutritional chain. Geographical distribution caused by genetic factors is usually beyond the problems of geomedicine.

According to the above definition, it is the effects of the common - the outdoor - environmental factors that are taken account of in the geomedical field. Important cases in occupational medicine are excluded because environmental factors inside buildings are not dealt with.

We can, of course, find many border-line cases that will raise doubt. As an example can be mentioned harmful radioactive radiation inside buildings. If the radiation derives from underground, neither from building nor from objects in the building, it is obvious that we are concerned with a geomedical question. Genetic problems caused by such radiation influence should naturally be considered in geomedicine. A large number of other border-line cases could also be mentioned.

So vast is the geomedical subject that it has to be subdivided. A simple and comprehensible starting point could be a division based on different groups of environmental factors. Until now nutritional conditions have most frequently been dealt with, but also many other differences deserve to be taken account of.

SOME FACTORS INFLUENCING CHEMICAL COMPOSITION OF SOILS

A fairly good synopsis on the distribution of different elements in the bedrock exists. Likewise, a large volume of data is available on the chemical composition of water from various sources. On the other hand, our knowledge of soil properties related to elements important in geomedicine is relatively limited. We need to find out more, not only about total contents, but also about more or less easily soluble fractions. Of special interest is information on the amount of elements available to the plants.

Some plant materials are the basic food of human beings either directly, or indirectly after having been animal fodder. Waste material returns to the soil (Fig. 1).

Comprehensive investigations have been carried out to illustrate soil chemistry and plant growth relationships. A large part of these studies deals with the interference of chemical factors on the quantity of the harvest. The problem of the importance of soil conditions for the chemical composition of the plants remains to be more thoroughly investigated. The circulation of

Circulation:

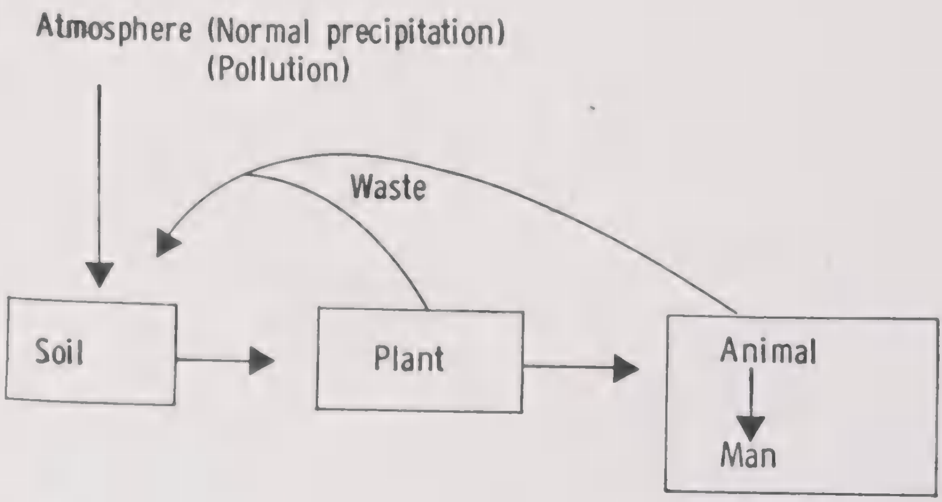

Fig. 1. Important circulation processes in the nature.

substances soil-plant-animal-man and back with waste material to the soil are processes dependent on many factors and, therefore, difficult to study. This is the main reason for our limited knowledge on the subject.

Pollution, which relates to our modern industrialized society, has raised special complications. Certain elements which earlier generations of organisms have only had little contact with, may be particularly dangerous. Nowadays there is a lot of talk about lead, mercury, and cadmium. However, several other elements may come into focus in the future.

Fig. 2 shows the factors which influence soil formation. We ought to notice that the climate includes both physical and chemical factors. Differences in the chemical composition of precipitation have influenced the soil. The original mineral composition of parent material in which the soil formation taken place has, of course, an interference on the chemical properties of the soil profile.

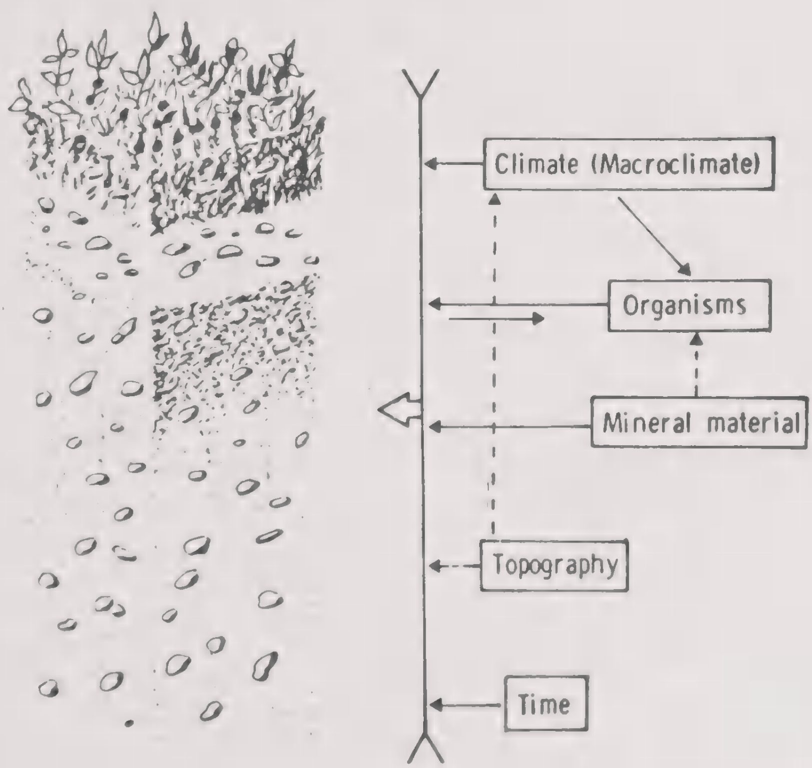

Fig. 2. Schematic presentation showing the influence of soil-forming factors.

EXAMPLES FROM A FEW RECENT NORWEGIAN INVESTIGATIONS

Registrations of the chemical composition of precipitation samples from different Norwegian stations showed huge variations. Possible influence of the atmospheric chemistry on soils makes an interesting study.

Analyses of systematically gathered forest humus samples were started. The sampling was carried out in the productive forest areas in the countries North-Trondelag, Oppland, and Buskerud. In all, more than 3300 samples were collected. Later, the sampling was continued in Rogaland, Hordaland, and More and Romsdal but the results of analyses are yet ready. Regional distribution patterns for some of the elements are of special interest. Typical seawater elements like sodium, magnesium, chlorine, iodine, and bromine were more frequent in the humus in the coastal regions than inland.

One particular example may be mentioned — this is the small concentrations of selenium in the soils in inland areas with low precipitation [4,5] . Muscular degeneration in domestic animals due to selenium deficiency, was proved in these inland regions with a dry climate. As far as I know, this was the first time a relationship between the distance to the ocean, amount of precipitation, selenium content in soils, and a disease due to selenium deficiency has been demonstrated.

In the same districts in Norway where selenium deficiency occurs, goitre is likely to have been quite frequent. Both selenium and iodine are brought to the soil surface by precipitation. In young soils, we usually have a greater risk of deficiency of these elements than in older soils. Where there has recently been glaciation, as for example in Scandinavia, the soils are young. How-ever, we also find young soils where rapid soil erosion takes place, as in many mountain districts. It will be of interest to make a comparison between the Chinese Keshan disease [6] and diseases caused by selenium deficiency in Norway.

Due to the differences in the composition of the mineral material, and great variations in the ability of different plant species to take up selenium from the soil, we may find some local areas

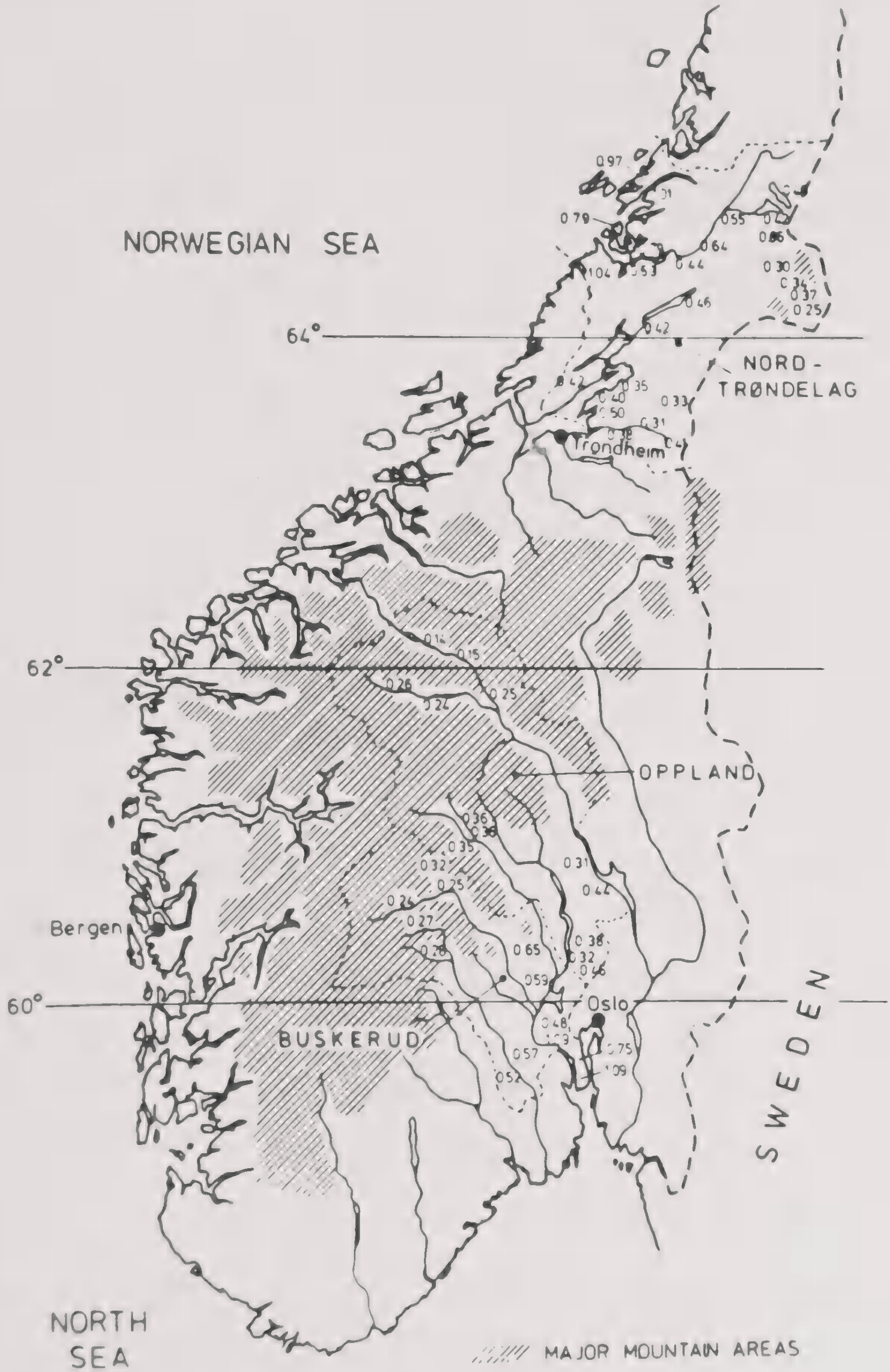

Fig. 3. Regional distribution of selenium in humus layer in Norwegian forest soils (ppm).

with selenium toxicity in districts generally poor in selenium.

A study of another character is taking place in relation to geochemical prospecting. Such investigations were earlier concentrated on stream sediments, but were then extended to the collection of humus samples as in the forest soil investigations, and later also to other sample types.

A large geochemical investigation is being carried out in the northern hemisphere - above 66^{0}N – in Norway, Sweden, and Finland. The state geological research institutions for the three countries are responsible for these registrations. The Greenlandic Geological Survey has also participated to some extent. A total of six sample types are to be taken: water, stream sediments, stream mosses, stream peat, terrestrial humus, and morainic soil material. Up to now an area of 170,000 km^2 has been covered with one sample plot per 30 km^2. The analyses take time, but so far we have the results of 27 elements in stream sediments and 16 in moraine samples for an area of approximately 100,000 km^2.

Pollution material from the atmosphere comes down to the soil surface and will then be included in the soil. Animal husbandry is difficult in the vicinity of aluminium factories due to fluorosis. Corresponding damage has been proved on the wild red deer population [7]. In contrast to India we have encountered problems from naturally high fluorine concentrations in Norway.

Acids from combustion gases give acid precipitation that under unfavourable conditions has caused fish death in the water courses [8].

When considering pollution effects, it is important to have the best possible knowledge of natural processes. It is necessary to know what we can call background values when attempting to find what consequences the pollution may have.

There are some specific natural processes that may give a valuable basis for pollution estimation. In 1967 we found in Norway a natural lead poisoned area with up to 11% lead in the upper soil horizon. Later we have proved natural toxication of soil by copper and nickel respectively, and furthermore a combination of zinc, lead, copper and cadmium and finally a combination of hea-

vy metals and sulphuric acid. In all cases, the toxic elements were derived from the bedrock by chemical weathering and were transported by percolating groundwater in sloping terrain. The poisoned patches are formed on places where the water currents reach the soil surface. Each proved poisoned area covers only a small space from some m^2 to hectares [9,10].

No vascular plants occur in the area with the highest heavy metal concentrations. At somewhat lower contents, there are specific plant species. Some good grazing plants resist great lead and copper concentrations in the soil, but will also take up a lot of these elements. A fodder experiment with *Deschampsia flexuosa* grown on a lead poisoned area showed that rabbits, after 4 weeks, had an extra accumulation of lead in liver, kidneys, and bones.

Each year a number of sheep die in Norway due to copper toxication, without the source of the element being found. The discovery of natural copper poisoned areas may be of help to find a clue. However, such poisoning effects seem in many cases to be caused by deficiency in molybdenum, i.e. another geomedical factor [11].

In Norway there is probably a large number of naturally poisoned areas still to discover. When considering solutions to pollution problems in our industrialized society, it is important to study natural processes in more detail.

FINAL REMARKS

In attempting a general review on geomedical problems in a certain district, it is natural to raise questions on basic material for characterizing the environmental factors. For some physical factors such as climate, it should, in principle, be easy to find data. We have many examples of special medical arrangements related to certain climatic regions or climatic situations. The Nordic Council for Arctic Medical Research is a typical example worth mentioning.

The interest will, however, mostly be related to chemical differences in the environment. It is easy to understand that nutritional problems play an important role in geomedical relationships. But reliable descriptions of the composition of food are of-

ten difficult to obtain. It may be mentioned in this connection that in Finland a very comprehensive and precise food investigation took place a few years ago*. The Finnish investigation was apparently started due to a discussion on a possible relationship between chemical soil differences and the frequency of cancer in human beings.

Many important and difficult questions related to the circulation processes soil-plant-animal-man and back with waste material to the soil, are still unsolved. Furthermore, pollution problems of industrial and urban character complicate the matter. Increasing attention is paid to trace elements, both those that are necessary for living organisms as well as those which cause injury. In geochemical literature we can find information on the distribution of various elements[13-15]. A few other valuable books may also be mentioned[16-18].

The food used in most households comes from many different places. An exception here is the vegetarians who produce most of the food for their own consumption.

The water supply is often of local character. In districts with scattered population, the water quality may vary greatly. Some inorganic matter of interest in human nutrition is included in the water.

In such a complicated subject as geomedicine, it is necessary to pool contributions and exchange ideas among scientists with different backgrounds. Close collaboration across previously established subject limits is necessary when many difficult geomedical problems are to be solved.

As we are now to plan cooperation between our two Academies, geomedicine is perhaps one of the subjects we should take into consideration.

* *Mineral elements in Finnish Crops and Cultivated soils. Acta Agric Scand. suppl., 20, 1978*

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THE MAIN PROBLEMS OF ASIAN CONTINENT TECTONICS

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Asia is not only the most spacious of the continents, it is also the most complicated in structure. While all other continents have one old Early Precambrian core, Asia possesses several cores such as Siberian, Sino-Korean, South Chinese, Hindustan and Arabian, in addition to smaller old massifs. Its main trend was at first the destruction of old Early Precambrian continental crust with the formation of mobile belts between the fragments, and then agglomeration of these fragments, their collision, piling, and partial squeezing out of the material composing the mobile belts in the form of folded-mountain ranges.

LARGER CRATONS

The Siberian craton is separated from the East European and Sino-Korean by the Ural-Okhotsk (Ural-Mongolian) mobile belts with meridional strike in the northwestern part (the Ural-Siberian belt) and latitudinal strike in the southeastern part (Central Asian belt). The inner structure of the Ural-Siberian belt is not

known well enough, as it is deeply buried beneath the sedimentary cover of the West Siberian plate over a greater part of the area of its development.

The second largest mobile belt of Asia — the Mediterranean belt – stretches eastward from Europe and Northwestern Africa, dividing the East European craton from the African-Arabian one and the Sino-Korean craton from the Hindustan craton. East of the Caspian Sea (Turan and Tien Shan), the Mediterranean belt is practically contiguous with the Ural-Okhotsk belt, the boundary between them not being quite clear mostly due to influence of the sedimentary cover of the Turanian plate. In the southeast the Mediterranean belt is connected with the East Asian belt via Himalaya, Indochina, Indonesia and Philippines.

SMALLER MASSIFS: MICROCONTINENTS

A number of smaller blocks, located between and within the belts are massifs of the old continental crust which played the role of microcontinents in deep-sea basins of the oceanic-type in mobile belts, such as Kazakhstan-North Tien Shan, Tuva-Mangolian, Kerule, Aragun, Zeya-Bureya, Khanka massifs in the Ural-Okhotsk belt, the Transcaucasian Karakum, Afghanistan-Tajik, Badakshan-Nuristan, Central Afghan, Tarim, Tibet, Sinoburmanian, and Indosinian massifs in the Mediterranean belt, and south Kamchatka, Central Okhotsk-Sea, Japanese-Sea in the East Asian belt.

The continental crust of these massifs is mostly of the Archaean age. The early Proterozoic protogeosynclinal systems, of the Arvalli type in Hindustan occupy a subordinate place in their structure, and are most probably of the ensialic origin. It means that they were formed on the continental and not on the oceanic crust. These blocks represent fragments of a supercontinent that appeared at the end of Early Proterozoic (or even in Archaean) and then underwent destruction. This is confirmed by unconformable cutting of the inner craton structure by boundaries of the mobile belts. This implies that the mobile belts (except, possibly the East Asian one), originated in the process of disintegration of an Early Precambrian supercontinent. The ophiolites help in determining the time of continental disintegration.

In the Ural-Okhotsk belt the oldest ophiolitic belts along its eastern periphery (Yenisei ridge and East Sayan) are of the Middle Riphean age. Late Riphean ophiolites have also been mentioned in the boundary zone between North Tien Shan (a part of the kazakhatan-Tien Shan microcontinent) and Middle Tien Shan. It may be surmised that the development of the Ural-Okhotsk belt took place in the Middle or Late Riphean. However, the Lower Palaeozoic ophiolites are very common in the Urals, Tien Shan, Central Kazakhastan, Altai-Sayan – Mongolian area and Transbaikal region suggesting that the maximum opening of the Ural-Okhotsk geosynclinal basin occurred towards the end of Early Palaeozoic.

In the Mediterranean belt Late Riphean ophiolites are known in Morocco, on both sides of the Red Sea and presumably in southern, Trungson ridge in Vietnam. Early Palaeozoic ophiolites are known from North Caucasus, Qilianshan (China) and North Vietnam forming the northern belt. The southern part of the belt had undergone intense diastrophism in early Palaeozoic, followed by a long period till the end of Palaeozoic or the beginning of Mesozoic when it became a platform characterized by sedimentary accumulations as discernible in Arabia, central and southern Anatolia, the greater part of Iran, southern Transcaucasia, central and south Afghanistan and the Pamir, Pakistan, the Himalaya, Tibet and Burma. All these regions during the Palaeozoic belonged to the gondwanaland evident from similarity of faunal and floral complexes, the remarkable monotype character of the sections, and the paleomagnetic data. It appears that somewhat earlier, at the end of the Proterozoic and beginning of Palaeozoic, the Gondwanaland and incorporated Indosinia which as early as Ordovician-Silurian was an independent microcontinent.

The time of development of the East Asian belt is likewise Riphean to Early Palaeozoic, being conformable with the data on the Ural-Okhotsk and Mediterranean belts. At the same time the Siberian, Sino-Korean, South Chinese, Indonesian, Kazakhstan North Tien Shan, Tuva-Mangolian and other massifs were separated. On the contrary, the Gondwanaland that embraced a considerable area of southern Asia was a real supercontinent since the end of the Precambrian.

If the main geosynclinal belts of the future Asian continent originated in the Middle (?)-Late Riphean, the first stage of their development can be determined as the Baikalian, as a result of *the Baikalian tectonic cycle.* In the areas of the Polar Urals, Timan, and a considerable part of the Rechora plate, and on their continuation in the Barents Sea aquatoria, the development of geosynclinal Baikalides is accepted without question. The same can be said of the Yenisei ridge and the eastern cost of the Red Sea. In many of these regions the transition from geosynclinal stage of development to the orogenic one accompanied by formation of synkinematic plutons of granitoids, took place as far back as in the middle of the Late Riphean (at the level of 850 m.y.). this epoch is considered as the earliest one of the Baikalian tectogenesis. The next epochs are attributed to the Riphean-Palaezoic boundary.

PALAEOZOIC-MESOZOIC TECTONIC CYCLES

The *Caledonian tectonic stage,* that commenced towards the very end of Precambrian and ended in Devonian, was of great importance in the formation of the continental crust and the evolution of recent structures of the Asian continent. The first Salairan epoch at the end of the Cambrian caused tangential squeezing, piling, regional metamorphism and granitization all over the world. In the Altai-Sayan-Mongolian area it resulted in the cratonization of a vast area situated near the southern margin of the Siberian platform.

The first proper Caledonian epoch, known as the *Taconian* event at the end of the Ordovician and beginning to middle of the Silurian, terminated the spreading (opening) of the oceanic-type crust in the Ural-Okhotsk (except the Urals) and the Mediterranean belts. This diastrophism was accompanied by intensse granitization in Central Kazakhstan and the North Tien Shan leading to considerable cratonization. The next epoch of diastrophism towards the end of Silurian and beginning of Devonian considerably affected the Urals and Middle Tien Shan and culminated in the geosynclinal development of the mountains of Altai, West Sayan, Qilianshan, Central Qinlin, Cathaysia and Laos-Vietnam system of Indochina. It was accompanied by formation of thick volcano-plutonic belts along the eastern periphery of the Kazakhstan-North Tien Shan and Khanka microcontinents. The last epoch of

Caledonian tectogensis occurring in the middle-end of Devonian times in the Altai-Sayan area resulted in the cratonization of central Kazakhstan, North Tien Shan and west of the Altai-Sayan area.

On the whole the impact of the Caledonian tectogenesis, and especially of the granitization spreading far beyond the Caledonian geosynclines, was rather widespread in Asia. It may be mentioned that the time boundaries between the above-mentioned epochs are to a considerable extent conventional, and the culmination impulses of diastrophism within these epochs were far from being synchronous in separate folded systems, and even in some segments of the same system.

The *Hercynian stage of tectogenesis* was decisive in the evolution of the Ural-Okhotsk belt, except its extreme eastern part and the northern part of the Mediterranean belt (Palaeotethys). It is weakly expreseed in the East Asian belt. The first impulse of the Hercynian tectogenesis occurred in the middle of Early Carboniferous (the Greater Causes, Central Kazakhstan, Altai, and Japan); and the subsequent one towards the end of Early Carboniferous (Urals, South Tien Shan, Central Kazakhstan, Altai, South Mongolia and adjacent regions of China, and Japan); and in the middle of Permian (an Urals). In the extreme south of the South Tien Shan (the Gissar Ridge) and in the northern zone of the Pamirs during the middle of Early Carboniferous rifting took place which led to the opening of secondary basin within the oceanic crust on the northern margin of the Gondwanaland. This process of rifting must have involved the adjacent parts of the Afgan-Badakshan in the west and Kunlun in the east. Thus the Hercynian geosynclinal development lasted till the end of the Permian – beginning of the Triassic.

The *Cimmerian tectonic stage* was manifest in the areas fringing the Pacific Ocean. The Indosinian epoch of Indochina corresponds to the Early Cimmerian diastrophism of Europe. The Verkhoyanie or Kolyma epoch of the northeastern of the Late Cimmerian epoch. Both the epochs are pronounced in the Crimean mountains whence their name originated. In the northern part of the continent the Early Cimmerides incorporate the folded systems of Novaya-Zemlya Mountain and the Taimyr.

The Early Cimmerian deformations put an end to the submergence of graben troughs (taphrogeosynclines) on the basement of the Skiphean and Turanian plates in northern Afghanistan (the Bandi-Turkestan zone), in northern Iran, and to the east of the Mediterranean belt which originated in the Late Palaeozoic and countinued to develop actively until the second half of the Permian and in the Triassic. As a rule, they did not pass the intermediate stages with accumulation of sedimentary formations of various depths on the thinned out or normal continental crust. All these structures are characterized by faulted margins, short duration of their existence, intense submergences in the Permian and Triassic leading to formation of unusually thick flysh-type volcanogenic-terrigenous 'black shales' series and folding and granite formation in the Late Triassic.

Structures of a different type (geosynclinal) evolved in the Early Cimmerian epoch simultaneous with the above-mentioned isolated of semi-isolated troughs. These structures are represented by large and extended zones dominated by subsidences in the Middle and sometimes Early Palaeozoic, Carboniferious, and Permian times. They stretch from the Belitung Island in West Indonesia through the central part of the Malaya Peninsula, through Western Kampuchea, central and northern Thailand, northwestern Laos, western Yunnan in the upper course of the Yangtze River, northern Tibet to western Kunlun, and perhaps the North Pamir and western Hindukush. Some deep-sea volcanogenic or terrigenous-siliceous formations accumulated on the oceanic-type crust. This system is marked throughout by intense dislocations at the end of the Triassic or at the Triassic-Jurassic boundary, and by the belts of granites and ophiolites. They are fringed by vast Palaeoshelf zones.

Widespread Early Cimmerian movements in southeastern and central Asia have led to recognition of an independent *Indosinian epoch* of tectogenesis in the Permian-Triassic, the epoch is of the same great importance in the evolution of the Asian continent, as the Caledonian, Hercynian and Alpine epoches were: 118

ALPINE TECTONIC CYCLE

Along with the closing of the Paleotethys, active opening of the Mesotethys took place of it, resulting from the breaking down

of the northern margin of the Gondwanaland towards the end of the middle Palaeozoic and beginning of Late Palaeozoic. It is represented by development of deep-sea suit and ophiolitic belts in southern and northern Burma, central Tibet, northern Karakorum, South Pamirs and Afghan-Badakhshan. The closing of that basin within the crust of the oceanic-type took place mostly in the Late Cimmerian epoch towards the end of the Jurassic and beginning of the Cretaceous. In Indochina, Tibet and in the Pamirs the origin and development of the Mesotethys at the end of Devonian—the Carboniferous was accompanied laterally by the development of volcano-plutonic arcs in the marginal parts of the Palaeotethys. The closing of the latter in the Permian-Triassic proceeded simultaneously with the development and subsequent opening of the Neotethys whose axial zone is recognizable by ophiolites of the Zagros, Makran, Baluchistan, Kohistan, the Indus-Tsangpo zone and western Burma and their continuation into the Indonesian arc. The spreading of this basin continued up to the Late Cretaceous and Palaeocene. Towards the end of the Eocene, it was subjected to strong squeezing resulting in the obduction of ophiolites over the margins of the Arabian and Hindustan platforms. These events signified the beginning of the *Alpine epoch* of tectogenesis.

By the end of the Oligocene times the subduction of the oceanic-type crust had been completed and the Afro-Arabian and Hindustan plates collided with the Eurasian continent. The last chapter of the history of the Asian continent is characterized by repeated renewal of the outgeosynclinal orogenesis related to the collision of continental blocks. The greater part of mountains of Asia appeared in areas which completed their geosyclinal development in the period Early Precambrian to the Late Jurassic Early Cretaceous. As a rule, each successive orogenesis began within a geosynclinal system and then spread widely over its earlier consolidated continental framework. This process is confirmed by development of molasses, granitoids and radio-isotopic rejuvenation of rocks. Judged by such evidence, the Baikalian mountain region was subject to almost continuous orogenic activization throughout the Phanerozoic due to impulses coming from the south. The only relatively quiet period was in the Late Cretaceous and Early Paleogene. Then followed the last activization which resulted in the formation not only of the Baikalian mountain but also of all mountains from the Tien Shan and Pamirs to

Qinlin and Verkhoyanie.

RIFTING AND MARGINAL BASINS

Besides development of mountains, one of the manifestations of the tectonic activities was rifting. The rift systems were repeatedly originating and fading out in the area of the recent Asian continent in the Riphean and Middle Palaeozoic in East Siberia and North China – in Late Palaeozoic in Hindustan, in Triassic in the Tien Shan, and in Late Jurassic-Early Cretaceous in Transbaikalia. To the newest epoch belong to the Baikal and Mom rift systems, which are still in the process of development. The most intensive process of rifting began in the Cenozoic times in eastern Asia, which led to the formation of the Pacific marginal seas and the parallel continental rifts in eastern China.

Significantly, the marginal volcano-plutonic belts were developing in the same peripacific zone in the Late Mesozoic. Since the end of Triassic the sedimentary covers of the Sino-Korean and South Chinese platforms have been folded. the maximum magmatic activity in marginal-continental belts shifted northwards with time. Thus from the Cathaysian belt Late Jurassic - Early Cretaceous in Korea, and the Sikhote-Alin-in southwestern Japan - Early first half of Late Cretaceous) to the Okhotsk-Chukotsk belt (Late Cretaceous-beginning of Palaeogene) in the north. Noteworthy is the fact that the time of origin and development of the adjacent marginal seas similarly changed in the same direction, i.e from the middle of Cretaceous in the case of the Chinese Sea to the end of Paleogene in the case of the Sea of Japan and the Okhotsk Sea. the paragenetic relation between these two processes is obvious. Some researchers explain this regularity with the help of a model depicting successive subsidence of the Paleopacfic mid-oceanic ridge segments under the continental lithospheric plate of Eurasia. Judging by the strike of the ancient magnetic anomalies, this range was oblique to the edge of the continent. Originally subduction of the oceanic plate caused formation of marginal continental belts of the calc-alkaline magmat- 120
ism, then the collision of the continental margin with the mid-ocean ridge resulted in the destruction of the former active margin and the opening of deep-sea basins in the marginal seas. The processes of subduction shifted towards the ocean to the recent island-arcs. The specific structural features of the eastern margin

of the Asian continent are certain to reflect an interaction between the microplates of the marginal part of the Eurasian lithosphere plate and the oceanic plates of the Pacific ocean, but the character of this interaction has not been thoroughly studied so far.

HINDUSTAN SUBCONTINENT

The southern part of India and Sri Lanka made up of very old crystalline rocks, some of which formed more than 1.5 billion years ago, formed an isolated small continent that touched the island of Madagascar. The present-day floral and faunal similarity of the Madagascar and South India is remarkable. The Miocene sediments (25-30 m.y. old) occur in the foothills of the Himalaya and in the coastal belts. The plants growing in Kerala are similar to those that occur in the Miocene (25-30 m.y. old) of the Himalayan foothills, and in the extreme southern part of India and Sri-Lanka there were forests of *Notofagus* which now grows in the Falkland islands. These facts indicate the just 25-30 m.y. ago, the South Indian shield was situated many hundred kilometres to the south of the present position. Palaeomagnetic studies corroborate this deduction.

To the north of the Deccan continent stretched a vast seaway underlain with thin lithosphere, and dotted with islands forming arcs. The northward movement cf the Deccan (about 25 m.y. ago) folded and thrusted the sedimentary pile that had been emplaced in this seaway, giving rise to the Himalaya. Geodetic investigations carried out by Soviet geologists indicate that the peaks of Tien Shan and Pamir continue to rise at the rate of 18-24 mm / year.

SCIENCE, SCIENTISTS AND SOCIETY

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We are impeded in our endeavours to understand many relations by a language developed in a less scientific and technological time. Not only does the public not understand what science is but those who teach science and those who communicate science also seem confused.

I find it helpful to approach science, engineering and technology as processes and it is this simplistic approach that I share with you today. Each of the three processes - science, engineering and technology - generates a body of knowledge consisting of a data base, an array of methodologies and an array of concepts. It is the combined body of knowledge that is such a significant resource in the resolution of societal issues. Some societal issues, such as ozone in the stratosphere and carbon dioxide in the atmosphere, are truly global issues. Others, such as malnutrition, epidemics, acid rain and the unequal distribution of wealth, manifest themselves locally and regionally but are widely preval- 122
ent; these also are world issues.

It is not important whether you agree or disagree with the approach I take, but it is important that we endeavour to understand the very complex issues involved.

SCIENCE

Science is the process of investigation of physical, biological, behavioural, social, economic and political phenomena. *Process* is used in the collective sense to include everything the investigator does from the identification of the phenomena to be investigated to the assessment of the validity of the results. It includes the selection of methodology, the selection of instrumentation, the delineation of protocol, the execution of protocol, the reduction of data, the development of constructs and the assessment of the certainty or uncertainty of the results. The details depend to a large degree on the relative significance of observation, experimentation and theoretical modelling in the investigation. The legacy of these investigations is a body of scientific knowledge consisting of a data base, an array of methodologies and an array of concepts.

The integrity of scientific knowledge is derived from the integrity of the process of investigation. Misadventure in any step of the process, for whatever reason, compromises the integrity of the results.

In a very similar way, engineering is the process of investigation of how to solve problems and includes everything the investigator does from the acceptance of the problem to the proof of the validity of the solution. The body of knowledge generated by such investigations is engineering knowledge and again consists of a data base, an array of methodologies and an array of concepts.

TECHNOLOGY

Technology is the process of production and delivery of goods and services. The more parallel term to science and engineering is technological innovation — the process of investigation of the more effective production and delivery of a product or service, or the production and delivery of a significantly modified product or service, or the production and delivery of a new product or service. Process encompasses everything from concept to successful delivery. The body of knowledge generated consists of a data base, an array of methodologies and an array of concepts.

The three processes — science, engineering and technology — are synergistic. The degree of synergism and the rates of response are enhanced by the knowledge generated. The acquition of knowledge accelerates the rate of acquisition of more knowledge.

Many endeavours such as medicine and education are in part science, in part engineering and in part technology. Investigations of biological phenomena and learning phenomena are, of course, science. The terms medical engineering and medical technology are well integrated into our language. Educational engineering and educational technology are not. I suggest that endeavours to develop curricula and curricular materials are investigations into solving problems of communication and the design of environments which enable students to extend their knowledge and understanding of the physical, biological, social, economic and political world of which they are a part and to extend their knowledge and understanding of past and present aspirations, achievements and disappointments of the peoples of the world. As such, endeavours to develop curricula and curricular materials are educational engineering.

I am particularly intrigued by the concept of the schools as institutions of technology to produce and deliver services to students and through them to all society. As institutions of technology, the schools struggle with all of the problems inherent in a physical plant, management, a work force, product design and quality control. It may be that the crises we face in our schools today relate to the crises we face in many of our other endeavours in technology and that both are the consequences of the same or similar forces in society.

It is the integrated body of scientific, engineering and technological knowledge that has become such a rich resource — a resource of such value that nations, institutions and individuals who generate knowledge may become increasingly reluctant to place the knowledge generated in the public domain.

CONSEQUENCES OF TECHNOLOGICAL CHANGE

Three roles of this integrated body of knowledge are significant to this discussion. These are:

1) the basis of investigation of phenomena, the investigation of problem solving and the investigation of the production and delivery of goods and services — in short, the basis of the acceleration of the expansion of knowledge itself,

2) the basis of our knowledge and understanding of ourselves, of our relations with others and of our knowledge and understanding of the political, economic, social, biological and physical environments throughout the world — in short, the basis of our extension of our perceptions of ourselves and the universe, and

3) the basis of the efficient production and delivery of goods and services and also the effective use of those goods and services — in short, the basis of the support of technology.

The first, the expansion of knowle[illegible] enhances future capabilities. The second, the extension of perception, enhances the capacity to identify, to analyze and to make decisions essential to the resolution of societal issues. The third, the support of technology, promises to fulfill the desire for economic development and the benefits of goods and services and thus to resolve or ameliorate societal issues.

However, society is not home free with economic development and the benefits of goods and services. Every technological change, be it by transfer or by innovation and regardless of how great the positive impact upon society, also has a negative impact upon society. This is a statement for which there can be no proof. On the other hand, I know of no evidence that it is not true and I have for some years challenged audiences to cite examples of technological change for which it is not true.

The total consequences of technological change may be surprising. For example, the great success of medical technology in saving lives and enhancing the quality of life is also responsible for the intensity of many societal issues today. There are simply so many more of us to consume and to pollute. To recognize this is in no way to imply that efforts in medical innovation should be diminished, it does imply that issues related to high density populations must be addressed simultaneously.

The subset of society that derives the benefits may not be the subset that bears the burden of technological change. The time frame of the benefits may be quite different from the time frame of the negative impacts. And the magnitude of the benefits and the magnitude of the burdens of technology may be quite different. The challenge is to selectively use technology to enhance the quality of life and to equalize the distribution of benefits and burdens.

This sweet/bitter characteristic of technological change is not a unique characteristic of technological change but a characteristic of change of all social, economic and political change. The goal of technological transfer and technological innovation is to bring about change.

The scientific, engineering and technological community, a subset of the public, cannot solve societal issues. Only society can solve societal issues.

Societal issues have to do with the quality of life of this and succeeding generations. The decisions that must be made in the resolution of societal issues involve value judgements. Value judgements are shaped by the culture. Priorities within a culture must also be responsive to all social, economic and political pressures and to the abundance of both renewable and non renewable resources. In response to such pressures, priorities may change quickly and significantly.

The roles of scientists and engineers are to identify problems, to analyze problems in terms of the existing knowledge, to carry on further investigations to generate essential knowledge, to propose and develop options, to assess the probable total impact of each option on society, to communicate these assessments to the public and/or the surrogates of the public in such a manner that the assessments can be understood, and once the decision has been made, to participate in the implementation of the decision.

It is essential that decision makers understand the probable consequence of each available option, including the option to do nothing, sufficiently to make decisions consistent with the values of the society. This is as true for positions taken in regard to

social, economic and political negotiations and actions as for positions taken in regard to technological changes involving physical and biological phenomena.

Within the United States, there is increasing concern that the structure and practices of our courts are inappropriate to the resolution of litigation characteristic of a scientific and technological society and also increasing concern that the structure and practices of our educational system provide inappropriate preparation for life long participation in the resolution of societal issues. The first, the courts, is probably a national problem and I will not pursue that concern here. The second, education, is probably a world problem and I will comment briefly on education for life-long participation in the resolution of societal issues involving science, engineering and technology.

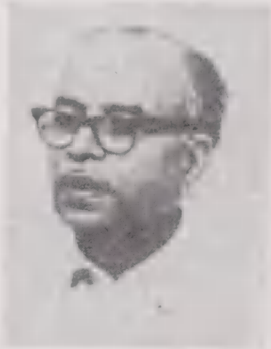
It is highly probable that most of what an individual knows and understands about science, engineering and technology ten to fifteen years after terminating the formal academic experience has been acquired subsequent to the formal academic experience. This follows from the rapid rate of expansion of scientific, engineering and technological knowledge. It is also highly probable that how much an individual knows and understands ten to fifteen years later is highly dependent upon the nature of the formal academic experience.

The education of an individual is the consequence of how that individual responds to a great multiplicity of enabling experiences – some provided for the individual and some created by the individual. Schools are, or should be in the business of providing enabling experiences for students. In so far as science is concerned, the academic experience should enable all students to extend their knowledge and understanding of science, engineering and technology throughout the next fifty or sixty years, at least at the level of the mass media. This is an impressive goal. My experience has been that in endeavouring to communicate with leaders such as legislators, lawyers, business personnel and communicators who have very little background in science, it is comparatively easy to bring them up to speed in recent scientific advances if that individual understands the nature of scientific knowledge and the nature of the process of investigation that generates knowledge. In particular, it seems to be essential that the

individuals, understand the uncertainty associated with scientific knowledge and have some concept of probability. Without that understanding, it is very difficult, if not impossible, to use scientific knowledge as a basis for decision making.

To develop this understanding, academic programmes must be based upon the investigation of selected phenomena and the current state of knowledge in selected areas in order to enable the student to develop an understanding of process, to develop familiarity with terminology and current concepts, to develop confidence in his or her capacity to understand things scientific and to discover the satisfaction of extending his or her own knowledge.

In summary, the ultimate goal is the expansion of knowledge and the use of knowledge to enhance the quality of life of this and succeeding generations. The pursuit of this goal can be, and should be, an exciting adventure.



SCIENCE AND VALUES *

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The *emblem* of the Academy has on it the Sanskrit inscription which says that a prime concern (dedication) of the Academy should be promotion and increment of human values. The *message* of the inscription has never been more relevant and needed than today. It brings to mind Einstein's deeply inspiring statement (November 1950) :

"The most important human endeavour is the striving for morality in our action. Our inner balance and even our very existence depend on it. Only morality in our actions can give beauty and dignity to life.

To make this a living force and bring it to c[illegible] consciousness is perhaps the foremost task of education.

The foundation of morality should not be made dependent on myth nor tied to any authority lest doubt about the myth or about the legitimacy of the authority should imperil the foundation of sound judgement and action."

Mankind is today at crossroads. One path leads to despair and annihilation, the other to possibilities of boundless advancement and enrichment - material, cultural and moral-spiritual. Man has now reached a stage in evolution when his very survi-

* *Abridged Version of the Lecture*

val and future evolution is possible only on the basis of Science and Ahimsa. *Ahimsa is love and nonviolence in word, thought and deed.* And this gives a new role and significance to education - that is to the teacher - as never before in human history. Hopefully, there is convergence of new far-reaching developments in diverse fields of science - from pure mathematics, and quantum machanics and cosmology to molecular biology, sociobiology and psychology - pointing towards a more unified world view of knowledge and values.

Perhaps, the most basic and most revolutionary concepts are of the infinite in mathematics (leading to Goedel incompleteness theorem) and the principle *of complementarity* in physics. And the supreme value is Ahimsa. What is of the utmost significance for the future of man is that Science is providing new insights into it, opening up new possibilities and new tools for practice of Ahimsa.

Gandhi described *Ahimsa* as the farthest limit of humility. And he stated : "It was only when I had learnt to reduce myself to zero that I was able to evolve the power of Satyagraha". The foundation of Ahimsa and Satyagraha is self-control, self-discipline. In *Hind Swaraj,* Gandhiji said that real Swaraj is self-rule or self-control. That is the Gandhian path, its core.

In March 1951, Einstein declared : "Revolution without the use of violence was the method by which Gandhi brought liberation of India. It is my firm belief that the problem of bringing peace to the world on a super-national basis will be solved only by employing Gandhi's method on a large scale.

Gandhi, the greatest political genius of our time, indicated the path to be taken. He gave proof of what sacrifice man is capable once he has discovered the right path. His work on behalf of India's liberation is living testimony to the fact that man's will, sustained by indomitable conviction, is more powerful than material forces and that seems insurmountable."

Any discussion of science and non-violence brings to mind the recent work of Konrad Lorenz and others which has shown that in Nature harmony is the normal rule and conflict an exception. Members of the same species never kill one another. Their

fights are either sport or ritual. There are a few species which deviate from the rule. And the greatest exception is the human species. Homo Sapiens torture and murder one another in war and peace, with an abandon, wantonness and brutality that has no parallel in Nature. It is Man's gift to Nature. Within a span of 40 years, two World Wars killed many tens of millions of people. How deep and pervasive are the effects of GHD (Greed, Hatred and Delusion)? More than 60 per cent of all world's research and development work in science and technology is directed to military end; $ 600 million a year is the global military expenditure, and it is still increasing. Some 700 million human beings are living today in absolute poverty - hungry, illiterate, and diseaseridden. The link between the two is apparent. Total comprehensive dis -armament and elimination of global poverty go together.

The food problem of poor countries has been aggravated by large increase in recent decades in consumption of animal protein by people in rich countries. A third of the world's yearly total output of cereals is used as animal feed to produce animal protein. About 5-20 kilos of vegetable protein go to produce a kilo of animal protein. This is done by industrial animal breeding methods of unspeakable cruelty. We cannot be cruel to animals and except that it will not harden human sensibility towards fellow human beings. In the long run, cruelty is indivisible; so is compassion. Alfred Kaestler (of optical pumping fame) at a UNESCO Conference in June 1978 observed that since animals are our "biological brothers", the time has come that in the interest of man's own future, "this relationship is legally recognised, "*The suffering of animals and of man is in the end not separable.* No longer the rigid Aristotle Descartes partition between human beings and other living creatures is tenable scientifically. It is totally unreasonable and harmful.

In the advancement of the theory and practice of Ahimsa, science and technology can play a major role of which the education is perhaps the most significant. Science opens up for man possibilities of moral experiments, and of insight into reality and ourselves as never before. It can help to liberate us from fear, greed, delusion and prejudice. And this continuing liberation opens up new horizons for exploration of nature and of Man's relations to nature. Every human action has a moral-spiritual component. And advancement of science can provide new opportu-

nities and new tools for enlargement and enrichment of the scope and depth of our moral endeavour.

Science and technology can tell us what can be done and what cannot be done. Science describes the limits of the possible. But *science cannot tell us what we ought to do. That decision is an ethical-moral decision.* Scientific truths and moral truths are not contradictory. *These are complementary.* It is the exploration and practice of the complementarity of scientific and moral truths that gives to life richness and beauty and happiness. The principle of complementarity in modern physics provides an illiminating and clear illustration of the complementarity approach. It can serve to help the appreciation of the complementarity, outside and *beyond* physics of science and humanism (morality).

There is, as it were, a hierarchy or levels of complementarities, beginning with the wave-particle duality in physics and leading to many levels, and to the complementarity of body and mind of *prakrati* and *purusha* of the *Sankhya Darshan.* There is also the complementarity of the two hemispheres of the brain which is of central importance for man's behaviour (R.W. Sperry, *Science,* 24, Sept. 1982). Bohr fervently hoped that the complementarity principle, in the near future will find a place in school education. It was his deep conviction that the approach suggested by the complementarity principle would serve as a most valuable guide in meeting life's problems, social and ethical. The complementarity approach is very similar to Jain and Buddhist logic. The chapter on Identity and Non-identity in *Gospel of Buddha* by Paul Carus is most illuminating for an understanding of the complementarity approach.

Science properly taught, can contribute much and effectively to the incorporation of the moral component in education - central to man's progress and even survival in the Atomic Age. The task is by no means easy : it demands sustained, imaginative, and dedicated effort. The need is desperate. The Academy can make a significant and pioneering contribution. A basic element of education ought to be the theory and practice of how to subdue our *real enemies : Kama* and *Krodha* (greed, hatred, delusion). Nothing could be of greater value in life and for the welfare and progress of the community and mankind. How to make even a beginning in this direction needs intensive study and research.

To man's great good fortune, science - perhaps unexpectedly - is now slowly but steadfastly moving towards a more unified world view which includes *both* knowledge and values as complementary and mutually reinforcing.